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A STUDY OF VARIABILITY IN THE BURT OAT [1]

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INTRODUCTION

The oat crop is the third most important cereal crop in the United States, being outranked by corn and wheat only. There are two general oat-growing regions, one northern and one southern. White oats are most popular in the colder north, while red oats are better adapted to the warmer southern States.

Burt, a selection made from a commercial field of Red Rustproof about 1878, is one of the principal representatives of the varieties of red oats. The original selection is supposed to have been made by a man named Burt, whose name the variety now bears. The exact place of origin is not definitely known but is believed to have been in Greene County, southern Alabama. It is probable that Burt, May, Early Ripe, and June are different names for the same variety.

The Burt oat is widely adapted and is commercially grown in the South and Southwest. It has long been recognized as a variable variety and its classification has been difficult. The variety contains strains resistant to crown rust, *Puccinia coronata* Corda, as well as strains resistant to loose smut, *Ustilago avenae* (Pers.) Jens., and covered smut, *U. levis* (K. and S.) Magn. The early maturity of Burt often enables it to escape injury from drought and rusts.

Recognizing the present economic importance and the potential breeding value of the variety, the writers undertook an extensive technical study to determine the nature and extent of its variability. As a necessary background for this investigation a wide review was made of the technical papers on oat classification and breeding. The variety proved to be far more variable, both in general characters and in kernel characters, than was previously realized.

Five characters have been studied, namely, spikelet disarticulation, floret disjunction, basal hairs, awns, and lemma color. Variability is found in all of these, as well as in general plant characters. The indications are that in some characters homozygosity may be attained, or at least approached, by pure-line selection. Association has been observed to exist between some of these kernel characters. No genetic analysis is attempted on the basis of the data presented.

The data presented in this paper, together with the literature review, are believed to be of especial interest to agronomists, geneticists, plant breeders, and botanists. They afford a basis for classifying not only the Burt oat but similar cultivated derivatives of *Avena sterilis* grown in the United States. Europeans long have designated the cultivated forms of *A. sterilis* by a separate specific name, just as both Europeans and Americans have desig-

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nated those of *A. fatua*. It is believed that Americans should make a similar distinction in name between the wild or ancestral form, *A. sterilis*, and its cultivated derivatives. Of the many names used, the designation *Avena byzantina* Koch is believed to have priority.

The literature of the Burt oat is reviewed below under three main divisions, namely: (1) Importance and distribution; (2) description and classification; and (3) inheritance of spikelet characters in oats. In general the literature is discussed in the order of its publication.

LITERATURE ON IMPORTANCE

It has been shown by Parker (*100*) [3] and Durrell and Parker (*30*) that certain strains of Burt oats are highly resistant to crown rust (*Puccinia coronata* Corda). This character adds to the value of the variety, for, as Parker has shown (*102*), crown rust is widely distributed in the United States and may cause appreciable losses, particularly in the Southeastern States. The investigations of Norton (*99*), Zavitz (*159*), Reed (*109*) and Reed, Griffiths, and Briggs [4] show that certain strains of Burt and Early Ripe, a variety probably identical with Burt, are highly resistant to loose smut (*U. levis* (K. and S.) Magn.) and to covered smut (*U. avenae* Pers. Jens).

Burt is one of the earliest maturing varieties in the United States. This character often enables it to escape destructive rust infection and injury from drought.

For many years it has been recognized by those familiar with Burt oats that so-called pure-line selections from this variety very often do not breed true. Norton (*99*) was one of the first to recognize this fact. Parker (*101*) found that the strain of Burt oats used in his experiments was not homozygous for resistance to crown rust, although it was considered a pure line with respect to the usually observed agronomic characters. Several theories have been advanced to explain this phenomenon, but as yet no explanation based on experimental evidence has been offered.

During the past 20 years a number of oat crosses have been made in which the Burt oat was used as one of the parents. Some of these hybrids have been found to be of considerable promise. Results of varietal experiments conducted by Warburton, Burnett, and Love (*144*) at Ames, Iowa, Ithaca, N. Y., and certain other stations show that hybrids of Burt and Sixty-Day have given favorable results. Stanton (*123*) states that one of the highest-yielding varieties at the Fort Hays Branch Station, Hays, Kans., is a hybrid between Burt and Sixty-Day.

LITERATURE ON DISTRIBUTION

The distribution of the Burt variety in the United States is very wide (fig. 1). Probably few oat varieties have proved as well adapted over so wide a range of conditions. Records of varietal experiments conducted at experiment stations in nearly all States from northern Florida to southern New York and from the Atlantic coast to the Rocky Mountains and also in California show that comparatively favorable yields have been obtained from Burt oats, or hybrids between Burt and other varieties, in most of the States in this entire area.

For the convenience of the reader, the extensive literature reviewed is grouped geographically as follows: (1) General; (2) Southern States; (3) Northern States, Canada and Alaska; (4) Great Plains States and westward; and (5) South Africa and Australia.

GENERAL LITERATURE

Carleton (*16*) states that the early Burt is among the earliest varieties grown in this country and that it is an excellent sort simply because of its earliness, especially in districts where there is liable to be a large amount of rust or where the dry weather sets in early.

Warburton, Burnett, and Love (*144*) present data on oat varietal experiments and on breeding experiments with oats, conducted in many different States and under widely varying conditions. They report on experiments conducted in Illinois, Iowa, New York, Pennsylvania, Virginia, Ohio, Kentucky, and Indiana. At many of the stations in these States, Burt or hybrids between Burt and other varieties have outyielded all others, and at nearly all stations the Burt oat ranked comparatively high in yield.

Wheeler (*149*) includes the Burt variety among winter oats, and gives the following description:

> Stems half spreading in early growth, many per plant, heads like those of Red Rustproof; grains bearded, dull yellow, long pointed, with many short bushy hairs at the base; the grains hang together like those of Red Rustproof; ripens fairly early.

[3] Reference is made by number (italic) to "Literature cited," p. 60-64.

[4] G. M., Reed, Marion A. Griffiths, and Fred N. Briggs. Varietal susceptibility of oats to loose and covered smuts. U. S. Dept. Agr. Bul. 1275. [In press.]

In the list of desirable varieties for the different States the Burt oat is recommended for spring sowing in Arkansas, California, Florida, Kentucky, Mississippi, Nebraska, North Carolina, Tennessee, Texas, Virginia, and West Virginia. The Burt oat is mentioned also as a suitable winter oat for Missouri, while for Oklahoma conditions it is recommended as a spring oat for most of the State and as a winter oat for the extreme southern border of the State.

Kilgore, Burgess, and Meacham (*62*) describe the Burt or Ninety-Day variety as one of the best, if not the best, of the spring oats for general sowing in North Carolina.

Garren (*44*) and Williams (*150*) of the North Carolina Agricultural Experiment Station found Burt one of the earliest oat varieties, and recommended it as one of the best for spring seeding under North Carolina conditions.

FIG. 1.—Map of the eastern and central United States showing distribution of the Burt oat in 1919

CONCERNING SOUTHERN STATES

Plumb (*104, p. 19*) states that Burt is a locally grown variety that does well in Mississippi, Alabama, Georgia, South Carolina, and in central and eastern Tennessee.

Warburton (*142*) states that the Burt oat, sometimes called Ninety-Day or May, occasionally is sown in the fall in the South. This variety is similar to Red Rustproof but is less hardy, and ordinarily is sown in the spring, as it usually does well from spring seeding. For this reason Burt is a desirable variety to use in reseeding badly winter-killed fields of oats.

Duggar and Cauthen (*29*) state that Burt often is preferred for seeding in the spring in all parts of Alabama, and that from Auburn southward Burt may be sown in the fall if seeded comparatively early. According to these authors Burt does not give as good results in Alabama as do some of the Red Rustproof strains.

Mooers (*80*) states that Burt has been the standard spring variety in middle Tennessee for a number of years and practically has superseded all others in the rest of the State. It is the earliest of the spring varieties,

and to this fact must be attributed its chief advantage, for it will make a fair yield when the later kinds fail for lack of moisture. Burt can not be used safely as a winter oat in Tennessee, as it is killed by even moderately cold weather.

Childs (*18*) observed that the Burt and Early Ripe varieties are very much alike. The kernels are long and lighter in weight and color than those of Red Rustproof. These varieties mature at about the same time as does Fulghum. One kernel of the spikelet is awned.

Nelson and Ruzek (*84*) found that Burt was not winter hardy enough to be dependable as a fall-sown variety in Arkansas, but that it was the highest yielding of the spring-sown varieties tested.

Nelson and Osborn (*85*) found that strains of the Burt variety generally figured among the highest yielders each year that spring-oat tests were made at Fayetteville, Ark. Burt strains led in yield during the 10-year period and were second only to Fulghum in a 4-year period. Burt has almost always produced grain of fairly good quality. Burt and Fulghum are said to be the best varieties for spring seeding in Arkansas.

Helm and Stadler (*48*) include Burt in the early spring-oat group, and recommend it as one of the varieties suitable for northern Missouri as well as for the central and southern parts of the State. They give the following description of this oat:

> A very early maturing variety of the Mediterranean group. It is somewhat spreading in early growth, though not so spreading as Red Rustproof. Under Missouri conditions the plants are taller and the heads longer than those of Red Rustproof. The head stem is not so straight as that of Red Rustproof and Fulghum. The grains are similar in form to those of Red Rustproof, and are bearded, but have short bushy hairs at the base and are dull yellow in color. At this station Burt oats have been the earliest maturing variety grown, maturing one to three days earlier than Kherson and Sixty-Day. They are remarkably resistant to smut and fairly resistant to leaf rust. Their yields have been high, and it is probable that they will be found a leading variety in this State.

Observations made by T. R. Stanton, and one of the writers (Parker) corroborate the statements of Helm and Stadler, at least for Clinton and Dekalb counties in northwestern Missouri. In company with R. O. Pixlee, of Cameron, Mo., they studied oat varieties on several farms in these two counties.

The Burt oat was introduced into this section of Missouri in 1888 or 1889 by James Chapman, who procured seed of Burt from his former home in Tennessee and sowed it on his farm about 2 miles west of Osborne, Mo. The Burt has been grown continuously since its introduction and the acreage has steadily increased until it probably is now grown more extensively than any other variety in this territory. Mr. Pixlee, who has been engaged in the elevator and grain business at Cameron throughout the period mentioned, has always encouraged the growing of Burt and has set aside seed of good quality for his customers. He has built up a special market demand for Burt for seed at the Kansas City and St. Louis markets, where several cars of Burt are sold each year, mostly for seed in southern territory.

The farmers interviewed who were growing Burt oat mentioned the following advantages of this variety: (1) Early maturity, (2) relatively high yields, and (3) freedom from smut. The fact that the Burt oat has maintained its place in this territory in competition with other varieties for more than 30 years indicates that it has characteristics which enable it to succeed under a wide range of soil and climatic conditions. This section of Missouri is not particularly well adapted to oats, and if it were not for the fact that Burt can be grown with a fair degree of success, the acreage and yield of oats in this section probably would be considerably reduced.

CONCERNING NORTHERN STATES, CANADA, AND ALASKA

Love (*67*) reports that the best combinations in oat crosses grown in New York are Burt with Texas Rustproof and Sixty-Day. In another paper Love (*68*) states that Burt and Sixty-Day hybrids and selections gave the best yields at Ithaca, N. Y., from 1907 to 1912.

Hickman (*51*), in reporting the results of varietal experiments conducted in Ohio in 1890 and 1891, refers to the varieties Rustproof and New Red Rustproof as "mixed" oats. Burt oats are believed to be a selection from Red Rustproof and the variable condition of Burt may be due to this recognized "mixed" condition in Red Rustproof.

Burnett (*15*) states that the Burt oat is popular in some of the southern Iowa counties, rivaling the Kherson in yield in sections where it is adapted.

Zavitz (*157*) reported that the Early Ripe (Burt) variety is the earliest oat among some 260 varieties grown at the Ontario Agricultural College. The grain is long and slender, giving a rather light weight per measured bushel. It seems evident that this variety is immune from the attack of smut.

The same author (*158*), in reporting on the results of a four-year study of the tillering of oats, found that the Early Ripe and Burt oats averaged 17 and 18 tillers per plant, respectively, compared with 14 and 17 for Sixty-Day and Kherson, respectively. However, Zavitz [5] states that Burt is not considered of much agricultural value in Ontario.

Georgeson (*45*), reporting on experimental work in Alaska, names Burt's Extra Early among the varieties grown. From the data he presents, the variety appears to be among the earliest maturing grown in Alaska. He states that oats are grown for hay and make excellent silage.

CONCERNING GREAT PLAINS STATES AND WESTWARD

Jardine (*55*) in a paper on dry-land grains mentions the Burt oat as being one of the most promising drought-resistant varieties.

Stoa (*126*) states that red, gray, or black oats are not common in North Dakota.

Martin (*76*) has reported extensive nursery and plat experiments with oats on dry and on irrigated land in western South Dakota. Burt (C. I. No. 293)[6] produced an average acre yield of 33.7 bushels on dry land in the eight-year period from 1912 to 1919, inclusive. It was exceeded in yield by only one other variety, a selection of Sixty-Day, which averaged 36.1 bushels to the acre for the same period. Martin observed that the Burt variety as grown is a mixture of kernels of various colors.

Montgomery (*79*) found that Burt outyielded all other varieties at the Nebraska Agricultural Experiment Station. It was found, however, that the Burt lodged and rusted badly under unfavorable conditions. He states that the early oats grown at the Nebraska station are of either a reddish or yellow color, while the late varieties, with but one exception, are white. The early maturity of yellow oats also has been recognized by Zavitz (*159*) in the experiments conducted at the Ontario Agricultural College.

Snyder and Burr (*121*) state that of the varieties tested at the North Platte substation in Nebraska, Burt is one of the earliest and has ranked with Kherson in yield. It is said to be a few days earlier than the Kherson.

Kiesselbach and Ratcliffe (*58*) found that Burt outyielded all other varieties at the Nebraska Agricultural Experiment Station over a long period of years.

Ten Eyck (*128*) found the Burt oat to be one of the earliest varieties tested at the Kansas Agricultural Experiment Station. He stated that it was a very hardy and drought-resistant variety and recommended it for western Kansas.

Salmon and Parker (*117*) describe a high-yielding strain of Fulghum oats distributed by the Kansas station under the name Kanota. Data on the comparative yield of Burt oats are included in the same paper. In plats at the Agronomy Farm in the four-year period from 1917 to 1920, inclusive, a strain of the Burt oat (Kansas No. 5020) was outyielded only by Kanota, Fulghum (Kansas No. 6084), and a strain of Red Texas (Kansas No. 5205). In the nursery experiments, the average yield of Burt (Kansas No. 5020) for the five-year period from 1916 to 1920, inclusive, was exceeded only by that of Kanota.

Ross and Leidigh (*115*) found that of the varieties tested in the Texas Panhandle the Burt oat made the best yields, and stated that it was an extremely early brown variety, resembling Red Rustproof in some characteristics, but earlier. In another publication, Ross (*116*) describes the Burt as having smaller kernels than those of Red Rustproof, variable in color, ranging from yellowish brown to dark brown or almost black, and often distinctly striped. Burt matured a little earlier than the Rustproof group and produced slightly lower yields.

McMurdo (*74*) found that a selection of Burt, made by W. G. Shelley, and grown by McMurdo simply as Burt, was the highest yielding variety at the Akron Field Station in Colorado. This selection later was named Colburt by C. W. Warburton. Coffman [7] recommends it for seeding on dry land in northeastern Colorado.

Hendry (*49*) states that Burt is meeting with favor among California farmers. Trials at the University Farm, Davis, Calif., are said to have shown that this variety, which is described as gray seeded, possesses advantages over the red and black varieties in the interior districts which may warrant its release for general cultivation. In California, Burt is early,

[5] Letter to John H. Parker, 1916.
[6] Accession number of the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Dept. Agr.
[7] COFFMAN, FRANKLIN A. CEREAL EXPERIMENTS ON THE AKRON FIELD STATION. U. S. Dept. Agr. Bul. 1287. [In press.]

possesses tall stiff straw, and fills early in the spring, often escaping the hot weather which stops the filling of the later-maturing varieties. Hendry thinks the Burt probably will not prove to be more prolific than the red or black varieties in the Coast districts and recommends it for only the interior of the State.

Florell (*36*) presents data on oat varietal experiments conducted at Chico, Calif. He states that—

> as a general group, the so-called red oats are preferable to all other types for the peculiarly hot, dry climatic conditions of the Sacramento valley.

He names Burt among the varieties of this group, but apparently does not consider it as one of the most important representatives of the group.

CONCERNING SOUTH AFRICA AND AUSTRALIA

Mundy (*81*) considers the Burt oat a variety of great promise in southern Rhodesia. It is said to be extremely rust resisting, producing a fine straw 2.5 to 3 feet in length, with heavy heads and grain of good quality. Seed of Burt is available in commercial quantities and can be purchased from South African seed merchants. He states (*82*, *83*) that the Burt oat did the best of all varieties under trial at the Arlington Sand Veld Experiment Station in Rhodesia. It was early and extremely vigorous but lacked the rust-resistant properties of Kherson. This latter observation is of interest, because in the article previously cited (*81*) he described Burt as extremely rust resisting, and in America it has been found to be more resistant to crown rust than the Kherson.

Archer and others (*4*) state that Burt is a good drought-resistant oat, suitable for conditions in West Australia and especially useful for early hay and early grazing.

LITERATURE ON DESCRIPTION AND CLASSIFICATION

The classification of the Burt oat has proved a difficult problem. Different strains have long been recognized as having varying characters and probably for this reason authors have classified Burt in different ways.

Duggar (*28*) and Duggar and Cauthen (*29*) describe this variety as follows:

> The majority of spikelets bear one bearded and one beardless grain, but some are double bearded and a few are entirely beardless. The grains are more slender than those of Red Rustproof oats, and are of a paler cream or brownish-yellow color. Most spikelets have only short bristles or none. The straw is taller and weaker than that of Red oats. The variety is tender and is adapted to spring sowing. It matures from 8 to 10 days earlier than the Red Rustproof oats. Burt and May are apparently the same variety.

Norton (*99*) states that—

> while *Avena fatua* has been considered the progenitor of the cultivated oats, some of the varieties, as the red oats of the South, are undoubtedly descended from *Avena sterilis*.

He believes it probable that a third wild species is represented by the common Burt oat of the Southern States.

Burnett (*13*) classes Burt as one of the typical varieties of Rustproof, which he groups with the red oats.

Carleton (*17*, *p. 97*) classifies Burt as belonging to *Avena sativa aristata* Krause, and describes the variety as "awned, hull white or light yellow."

Etheridge (*33*), in his classification of oat varieties, gives the following description of Burt:

> Culms semi-erect in early growth, otherwise similar to those of *Avena sterilis nigra;* sheaths, leaves, panicles, spikelets, and glumes similar to those of *A. sterilis nigra*, except that the glumes are shorter, ranging from 25 to 30 mm.; grains dull yellow, elongated, outer grains 18 mm. long, long-pointed; lemma glabrous, with 7 obscure nerves; awn usually present on the outer grain and frequently on the inner grain, seldom twisted; basal hairs usually present, numerous, short (1–2.5 mm.), fine; basilar articulation of the outer grain evident; rachilla of the outer grain short (2–2.5 mm.), strong, glabrous, persistent to the inner grain. Plants 5–8 dm. tall; medium early in maturing.

Etheridge obtained samples of Burt oat under the names Early Ripe and Red Rustproof. He classifies Burt as a variety of *Avena sterilis* and considers it one of the principal representatives of the red-oat group grown in the United States.

Waller (*141*) states:

> While the origin of some of the early maturing varieties is at present unknown, there is reason to believe that one at least, Burt, may have come from *Avena barbata*.

Warburton [8] believes that Burt probably is the result of natural crossing between varieties of *Avena sterilis* and *Avena sativa*.

Pridham (*107*) lists Burt and Early Burt among eight medium early maturing varieties tested in New South Wales and gives as one of the distinguishing characters that they closely resemble Algerian. He states that Algerian "is often of a pale brown tint in warm districts and dark brown in cool ones."

Archer (*4*), of Australia, also considers Burt a variety of *Avena sterilis*, and describes the variety as follows:

> Panicle, equilateral, spreading, erect, medium to long; spikelets, two grained, outer grain awned,

[8] Letter to F. A. Coffman, 1920.

basal articulation of outer grain very marked; glumes, long, coarse, long pointed, nerves 9-10, fine; length of glumes 26 mm.; husk, pale yellow, glabrous, nerves not prominent; awns, numerous, not long, fine, neither twisted nor geniculate; basal hairs numerous, short, fine, white; rachilla, glabrous, long, fine, persistent to upper grain; grain with husk (outer grain) length 17-18 mm., long pointed, narrow, practically no shoulder; grain without husk (outer grain) length 8-9 mm., brush long; straw, fine to medium fine, non-hairy. First node of rachis normal, straight, inclined to lodge; foliage, medium in width, medium to sparse, early growth, medium erect to medium spreading; stooling, sparse; season, very early.

Marquand (*75*), of the Welsh Plant Breeding Station, considers the Burt oat a variety of *Avena sterilis*, subspecies *culta*, and gives the following description of the variety, which is in close agreement with that of Etheridge (*33*):

Young plant sub-erect. Lower leaves with marginal hairs towards the base of the lamina. Stems slender. Average height of the plant 80 cm. Panicle small, sub-equilateral, branches sub-patent. Spikelets 2-3 grained. Glumes 26-30 mm. long, 7-8.5 mm. wide. Grains dull yellow, attenuate; usually both upper and lower grains provided with long slightly twisted but rarely geniculate awns. Lower grain 17-20 mm. long, 2.5-2.8 mm. wide, 1.9-2.1 mm. thick; basal articulation only partly solidified. Outer palea glabrous, long pointed, with the apex not upturned. Rachilla also glabrous. Basal hairs numerous but very short (0.5-2 mm. in length), forming compact tufts. Early in ripening.

Marquand (*75*) also called attention to the fact, apparently not recognized by many agronomic workers, but emphasized in the present paper, that the majority of the older varieties of oats and some of the more recent ones are not pure lines but consist of a number of strains, sometimes amounting to hundreds, differing in their properties in a greater or less degree.

In a conversation with the writers in September, 1921, Prof. N. I. Vavilov, director of the Bureau of Applied Botany and Plant Breeding, of Petrograd, stated that possibly the Burt oat is similar to the European type classified as *Avena sterilis byzantina*.

Different authors do not agree on the amount of natural crossing which occurs in oats. It is generally believed, however, that while some crossing occurs, the extent is not great. Reports by Rimpau (*111*, *112*), Jamieson (*54*), Norton (*98*), Peacock (*103*), Livermore,[9] Heribert-Nilsson (*50*), Hayes and Garber (*47*), and others, indicate that natural crosses occur to some extent. Several other authors, namely, Hunt (*53*), Pope (*105*), Babcock and Clausen (*7*), Love and Craig (*72*), and Fraser (*37*) indicate that natural crosses in oats are of extremely rare occurrence.

From the results obtained in these experiments the authors believe that natural crossing in the Burt oat occurs to a greater extent than has been generally believed, although not so freely as believed by Jamieson (*54*). However, it probably is true that sufficient natural crossing does occur to account for some of the aberrant forms which appear and possibly for some of the recurring heterozygosity of the Burt oat.

Variability in oat varieties has long been recognized. More than 15 years ago Webber (*147*) stated that few pure strains of oats existed, and that varieties frequently were mixtures of different types. Warburton (*143*) pointed out the urgent need for definite experiments and scientific methods for oat improvement. Welton and Gearhart (*148*) have stated that great variability exists in the physiological and other characters of the plants of oat varieties. The extent and nature of the variability existing in Burt has only recently been fully realized, but the same condition may exist, to some extent at least, in other oat varieties.

AVENA BYZANTINA KOCH AND ITS RELATIONSHIPS

The following are brief reviews of the available literature on the classification of oats, with especial reference to the taxonomic position of the cultivated varieties supposed to have been derived from the wild *Avena sterilis*.

Koch (*63*, *p. 392*) published the original description of *Avena byzantina*, as follows:

Glaberrima; Spiculae magnae, biflorae; basis flosculi inferioris pilis quartam ejusdem flosculi partem attingentibus obsita, superioris nuda; Flosculi aristati, glabri, laeviusculi; Palea inferior bifida; Aristae pars inferior tortilis, glabra, laevis.

He states that it is similar in appearance to *A. sativa* but differs in having both florets awned and the lower hairy. He states further that Petermann's *A. hybrida*, according to its description, has a hairy rachilla and floret base. Koch based his description on plants from the vicinity of Constantinople and stated that he had received similar plants from the collection of Thirke made near Brusa and had previously determined these erroneously as *A. sativa*.

Cosson (*22*) published a paper on the classification of the species of Avena, in which *Avena byzantina* C. Koch is listed with *A. hybrida* Peterm. as being synonymous with *Avena fatua* var. *glabrescens*.

[9] LIVERMORE, K. C. NATURAL CROSS FERTILIZATION IN OATS. 1912. [Unpublished thesis, Cornell Univ., Dept. Plant Breeding.]

Thellung (*130*) published a very comprehensive paper on the origin, systematic position, and cultural history of the cultivated species of oats. He used Koch's name *Avena byzantina* for the cultivated varieties which have arisen from the wild *Avena sterilis*. A description of *Avena byzantina* is given, together with the synonomy. This species had been called *Avena sterilis* forma *parallela* by Haussknecht, *Avena sativa* var. *biaristata* by Hackel, and *Avena algeriensis* by Trabut. Thellung predicted that by using rational selection methods a true-breeding race having *sativa* characters could be produced from *byzantina*. He states that the biological and ecological relations of *Avena byzantina* also serve to distinguish this species from *Avena sativa*. The experiments of Trabut in Algeria and experiences in the Cape Province of South Africa, in Australia, and in the southern United States have shown that the varieties derived from *Avena sterilis* are best able to withstand the climatic conditions found in these regions.

Schulz (*119*) also uses the name *Avena byzantina* for the cultivated varieties which are supposed to have arisen from the wild *Avena sterilis*. *Avena byzantina* is said to occupy an isolated position. Most of the varieties of this species resemble those of *Avena sativa* in appearance but may be distinguished from it by the method of articulation and other characters. Schulz stated that *Avena byzantina* may be called the Mediterranean oat, as it occurs in Spain, Algeria, and Mesopotamia. It is said that oats of this kind were known by the Greeks and Romans.

Schulz (*120*) has written a history of the cultivated oats, including their nomenclature. He uses the name *Avena byzantina* for the cultivated polymorphous varieties of the Mediterranean group. He states that many forms of *Avena byzantina* closely resemble *Avena sterilis*, while other forms can scarcely be distinguished from *Avena sativa*. The *Avena algeriensis* of Trabut is considered synonymous with *Avena byzantina*.

Zade (*153*) gives a description of the kernels of *Avena byzantina* which are sometimes found in oat seed. He states that this species somewhat resembles the intermediate resulting from crossing between *Avena sativa* and *A. fatua* but that the kernels are longer and the form of the kernel base intermediate, a very unusual condition for the products of the crossing above mentioned.

Zade (*155*) carried on studies with oat species and varieties. He considers that *Avena byzantina* probably has arisen from *Avena sterilis*, as *Avena sativa* has arisen from *Avena fatua*. He states that this morphologically distinct species is a true intermediate between the cultivated and wild oats.

The papers quoted above show unmistakably that the name *Avena byzantina* is used commonly to designate the cultivated varieties derived from *Avena sterilis*, and that it has been used in this sense since 1848, when Koch (*63, p. 392*) published the first description of this species.

Trabut has made detailed botanical studies of red oats and has published a number of papers (*131, 132, 133, 134,* and *135*), one of which has been translated into English (*135*). He holds that *Avena sterilis* has given rise to oats adapted to the warm countries and to saline soils, and *Avena barbata* has given rise to races adapted to dry countries. Experiments in the United States have shown the Burt oat to be adapted both to southern conditions and dry climates. Trabut believes that *Avena sterilis byzantina*, as he here names it, has largely lost the characters of the *sterilis* type and constitutes the last stage before reaching the cultivated form. With regard to it he wrote as follows:

> In 1907 M. Hackel wrote me that he considered this form as intermediate between *Avena sativa* and *Avena sterilis* and named it provisionally *Avena sativa biaristata*.

Hitchcock (*52, p. 110-113*), who describes oat species found in North America, states, apparently on the authority of Trabut (*135*) and Norton (*99*):

> The Algerian oat grown in North Africa and Italy and the red oat of our Southern States are derived from *A. sterilis*. A few varieties adapted to dry countries are derived from *A. barbata*.

Warburton (*143*) points out that—

> the theory that all our cultivated varieties of oats have not been derived from *Avena fatua*, but that certain forms adapted to warm climates have been developed from *A. sterilis*, is not, however, entirely new.

He cites Norton (*99*) as having previously held that idea and takes exception to the following editorial statement which precedes the English translation (*135*) of Trabut's article:

> The prevailing belief that oats can not be grown in the southern United States is probably based on the fact that all the experiments made there have been with cold-climate oats. A great deal of money has already been lost by such attempts, foredoomed to failure because of unsuitableness of the material, although suitable material might have been had, and the country's wealth thus enormously increased had growers studied the genetic history of the cultivated oats earlier.

Warburton apparently believes these statements to be misleading and er-

roneous because he states that oat growing in the South is a profitable farm enterprise and oat experiments conducted in the South have not been altogether with varieties belonging to *Avena sativa*, the northern oat group. He further states that the Algerian oats discussed by Trabut usually have been discarded from experiments in the South, as they appear to be inferior to the Red Rustproof both in yield and winter hardiness.

In a very complete paper on the general subject of the immunity of plants from infectious diseases Vavilov (*139*) describes *A. byzantina* as being absolutely immune from the oat smut, *Ustilago avenae*, highly or completely resistant to the attacks of crown rust, *Puccinia coronifera*, and susceptible to stem rust of oats, *Puccinia graminis*. He also states that this oat is geographically and phylogenetically distinct from ordinary European susceptible oats. If the variety thus described by Vavilov is the same as or similar to the Burt variety as known in the United States, his work confirms, in a general way, the opinions of American investigators on the disease resistance and distinct taxonomic position of this variety. In an earlier paper Vavilov (*138*) states his belief that *A. fatua*, *A. sterilis*, and *A. ludoviciana* may be regarded as the ancestors of our cultivated oats. He suggests the use of physiological tests in genetics and systematics. The cytological data of Kihara (*61*) and Nikolaewa (*88*) suggest cytology as a further method for use in classifying oat species.

Because of the apparent agreement of many features mentioned by these earlier writers as being characteristic of *Avena byzantina* with the characters of the cultivated varieties of red oats grown in the United States, it seems proper to propose that the name *Avena byzantina* be applied to the cultivated varieties of red oats in the South, in place of the name *Avena sterilis*, now used by nearly all American botanists and agronomists.

It will be recalled that a distinct Latin name, *Avena sativa*, is applied to the cultivated varieties derived from *Avena fatua*, while the cultivated forms derived from *Avena sterilis*, though differing just as widely from the wild *sterilis* as the varieties of *Avena sativa* differ from the wild *fatua*, are designated by the same Latin name as the wild species. It would seem logical to follow the usage of the European workers and apply the name *Avena byzantina* to the red oats grown in the southern United States.

This name would seem especially suitable when applied to such varieties as Burt and Fulghum, which in many respects are intermediate between *Avena sativa* and the red-oat group, until now designated as *Avena sterilis*. The writers have observed some forms of Burt kernels which very closely resemble those of *A. sterilis byzantina*, as illustrated by Trabut (*135*). The name *Avena byzantina* has been used in this sense by Trabut (*135*), and by Schulz (*119*), who states that many forms of this species closely resemble *Avena sterilis*, while other forms can scarcely be distinguished from *Avena sativa*. Schulz (*120*) considers the group of cultivated varieties designated as *Avena byzantina* to be polymorphous, a condition certainly characteristic of the Burt oat, as described in the present paper. Salmon and Parker (*117*) have suggested that the Fulghum oat may be of hybrid origin, the result of natural crossing between cultivated forms of *Avena sativa* and *Avena sterilis*, thus adding strength to the argument for the name *Avena byzantina*, as used in Europe.

As mentioned by Schulz (*119*, *120*), the *Avena algeriensis* of Trabut is considered synonymous with *Avena byzantina*, which would stand on the basis of priority.

Schafer, Gaines, and Barbee (*118*), in grouping Washington oat varieties, state:

> The specific name for cultivated red oats is changed to "*byzantina*" in this bulletin to distinguish them from the wild red oats, *Avena sterilis* L. *Avena byzantina* C. Koch is used in order to have a term to conform with *Avena sativa* L. as *A. sterilis* L. conforms with *A. fatua* L.

The name *Avena byzantina* was used by the above authors in response to a statement from T. R. Stanton, agronomist in charge of oat investigations, that the Office of Cereal Investigations was making this change in nomenclature on the basis of the information presented in the above literature review. The term *Avena byzantina* C. Koch (*A. sterilis* L.) was used in the Yearbook of the Department of Agriculture for 1922.[10]

[10] BALL, C. R., and others. OATS, BARLEY, RYE, RICE, GRAIN SORGHUMS, SEED FLAX, AND BUCKWHEAT. U. S. Dept. Agr. Yearbook 1922: 469–568. 1923.

INHERITANCE OF SPIKELET CHARACTERS

In reviewing the literature on the inheritance of particular characters in oats it has been thought best to summarize the results under the heads of the various characters studied in the Burt oat. These were (1) spikelet disarticulation, (2) floret disjunction, (3) basal hairs, (4) awns, and (5) lemma color.

SPIKELET DISARTICULATION

At maturity or in threshing the oat spikelet becomes detached from the pedicel on which it is borne. (Its morphology is discussed more fully later in this paper.) In different species and varieties this disarticulation of the spikelet occurs in somewhat different ways, which result in very different appearances of the tissues at the base of the lower floret or kernel.

According to Etheridge (*33*) the basal form of the oat grain has been little used in classifying oat varieties. He states that the callus, the somewhat swollen tissue at the base of the lemma, is an insignificant part of the oat grain. There is sufficient reason for believing that the character of basal form in the oat kernel is of more importance than his statement would indicate. The terms "sucker-mouth," horseshoe base, basal scar, cicatrice, and others have been used by various writers to describe the thickened indurated tissue at the base of the kernel which here is termed the callus.

Surface (*127*), Love and Craig (*70*), and Fraser (*37*) have studied the inheritance of the form of the base. The results obtained by all of these investigators indicate the dominance of the absence of basal scar, characteristic of *Avena sativa* varieties, over its presence, as exhibited by *Avena fatua*, *Avena sterilis*, and the cultivated varieties of the latter which here are grouped as *Avena byzantina*.

The writers have found this character to be of considerable interest, as in its genetic behavior it is one of the most constant of the kernel characters studied.

Etheridge (*33*) cites Denaiffe and Sirodot (*26*) as having characterized various forms of the base according to the obliquity of the scar produced by the detachment of the lower floret from its pedicel, but these authors do not relate the form of the base to the more definite character of articulation or nonarticulation. Böhmer (*9*) and (*10*) also mentions several forms of the base of the lower floret, but does not use them in his classification. Trabut (*135*) makes but little use of the basal form in his paper on the Origin of Cultivated Oats.

Surface (*127*) reports the results obtained from crosses between *Avena fatua* and *Avena sativa*, variety Kherson. He states that the wild form showed an expanded oval ring at the base of the lower floret and that in the cross with Kherson the basal form showing no scar (*sativa*) was dominant, or nearly so. He found the following characters correlated with the "wild" type of base on the lower grain: (1) "Wild" base on the upper grain; (2) very heavy awns on the lower grain of every spikelet; (3) very heavy awns on the upper grain of every spikelet; (4) heavy pubescence on the pedicel of the lower grain; (5) heavy pubescence on the pedicel of the upper grain; (6) heavy pubescence on all sides of the base of the lower grain; (7) heavy pubescence on all sides of the base of the upper grain.

Surface (*127*) detected exceptions to the linkage, or crossovers, between the factors for pubescent glumes and black glumes (about 0.7 per cent) and the inhibitor of glume pubescence and the factor for "cultivated" base (about 1.5 per cent). Bartlett (*8*) has reviewed the work of Surface, above cited, on linkage and crossing over in oats. He believes that some of the cases considered as linkage by Surface (*127*) can be interpreted in a simpler manner. For instance, if the first floret is awned, it is a fair assumption that the second is potentially the same, even though its position be such that manifestation of the character is a physiological impossibility. He suggests that a factor linked with the factor for cultivated base may be conceived as a partial inhibitor of the pubescence factor.

Wilds[11] found, in crosses between *Avena fatua* and cultivated varieties of *Avena sativa*, that the character of the base is determined by a single pair of genes, the *sativa* type being dominant. The *fatua* base showed perfect linkage with the factors for strong awns and dense basal pubescence.

Love and Craig (*70*), in crossing *Avena fatua* with *Avena sativa*, variety Sixty-Day, found that in the segregation of the F_2 generation the sativa-like form of base is dominant or partially so.

[11] WILDS, G. J. INHERITANCE OF GLUME CHARACTERS IN AVENA. 1917. [Unpublished thesis, Cornell Univ., Dept. Plant Breeding.]

A ratio approximating 1:3 was obtained, the wild form being recessive. They state that the same has held true in a large number of other crosses in which the "wild" type has been used. In studying the segregation in the third and fourth generations they found no yellow oat exhibiting the "wild" base.

These results agree with those of Surface (*127*), as would be expected, for Warburton and Stanton (*146*) believe that the *sativa* parents, Kherson and Sixty-Day, used by these different investigators are practically identical. It is known, however, that strains exist within each of these varieties which differ in kernel color and other characters. For instance, three pure-line selections from Kherson, namely, Albion (Iowa No. 103), Iowar, and Nebraska No. 21, all have white-glumed kernels.

Wiggans [12] studied the basal connection in the cross Red Texas × Swedish Select. In F_1 there was an articulation of the outer floret, but this was not so pronounced as in the Red Texas parent. All types were found in F_2, ranging from the Red Texas to the Swedish Select type. The plants were classified as having Red Texas base, intermediate, and Swedish Select base, giving a close fit to a 1:2:1 ratio. These data indicate that there is only one pair of factors involved in determining the basal connection in this cross. There was evidence of linkage between the Red Texas type of base and the Red Texas rachilla character.

Fraser (*37*), in crossing Burt and Sixty-Day, found the F_1 basal form to be intermediate. In F_2 a ratio of three Sixty-Day to one Burt type of base was obtained. His results pointed to the existence of linkage between the Burt type of base and the fully awned condition. There also was evidence of linkage between the Burt base type and the presence of medium long basal hairs. Fraser stated that 4.14 per cent of crossovers occurred between awns and base type and that there was 1.79 per cent of crossing over between base type and basal hairs. He states that the strain of Burt used as parental material in these crosses had a dense covering of mid-length hairs on the sides of the basal callus and that the lower kernel had an articulation much like that of *Avena sterilis*. The Sixty-Day parent had the base and articulation characteristic of *Avena sativa*. Basal hairs seldom were present.

FLORET DISJUNCTION

The florets of an oat spikelet are connected by the clavate segments of the rachilla. The articulation at the juncture of two segments is not very evident, owing to the structure of the spikelet. The base of the lemma of each floret is attached to the enlarged apex of the segment which bears it and entirely surrounds the slender base of the segment which bears the next higher floret. This latter segment therefore appears to grow out from the basal tissue of the inrolled lemma next below.

When florets of *A. byzantina*, the cultivated red oats derived from *A. sterilis*, are separated the rachilla segments bearing the second and third florets usually remain attached to the bases of those florets. When florets of *A. sativa*, the cultivated oats derived from *A. fatua*, are separated the bearing segments usually disarticulate from the base of the floret and remain attached to the face of the next lower floret.

The attachment of the rachilla segment to the base of the second and subsequent florets in *A. byzantina* is very firm. In threshing the florets of the spikelet often remain attached together. When they are forcibly separated the segment breaks near its base, as pointed out above. In *A. sativa*, on the other hand, the separation by disarticulation at the base of the floret takes place very readily.

Norton (*99*) apparently was the first American investigator to call attention to the firm union of the first and second florets with their connecting rachilla segment in the cultivated varieties derived from *Avena sterilis*.

Trabut (*135*) made use of this character in his classification of oats. He states, however, with regard to *Avena barbata* that—

> there is little difficulty in finding all the characters of *Avena barbata*, not taking into account the functioning of the articulation and the pilosity, two fluctuating characters without value, as we have seen in *Avena sterilis* and *Avena fatua*.

Etheridge (*33*) states that the specific character of connection of the kernels has not been used extensively before in the classification of cultivated varieties of oats. He found this character to be of great value for distinguishing the cultivated forms of *Avena sterilis* from those of *Avena fatua*. In his review of the literature on oat classification he refers to Denaiffe and Sirodot (*26*) and to Broili (*12*) as using the form and hairiness of the rachilla

[12] WIGGANS, R. G. THE INHERITANCE OF CERTAIN CHARACTERS IN A CROSS BETWEEN RED TEXAS AND SWEDISH SELECT OATS. 1918. [Unpublished thesis, Cornell Univ., Dept. Plant Breeding.]

as distinguishing characters in their classifications of oats. Schulz also is cited as having used the character of the rachilla connection to differentiate *Avena sterilis* from *Avena fatua*, *Avena barbata*, and *Avena wiestii*.

Von Tschermak (*137*) describes the linkage groups observed in crosses between cultivated and wild oats. There is absolute coupling between brittleness, or the falling apart of the spikelet on ripening, and complete beardedness. There is complete incompatibility of stiff hairs on the lemmas, as in the wild oat, and the yellow color of the cultivated oat. Brown floret color, as in the wild oat, and the glabrousness of the cultivated oat also are incompatible.

Wiggans [13] studied the breeding behavior of the rachilla character in a cross between Red Texas and Swedish Select oats. The rachilla disjunction of the F_1 kernels was very similar to that of the Red Texas parent, each rachilla segment remaining attached to the base of its floret when threshed. This character is more definite than the basal connection, but in F_2 all gradations from the typical Red Texas disjunction to the typical Swedish Select were found. The Red Texas type of disjunction was dominant, and it seems fairly certain that the kind of disjunction is determined by one pair of factors.

Fraser (*37*) has reported a cross of Burt and Sixty-Day in which he found that the "non-Burt" type of disjunction was dominant to the "Burt" type. He states that the Burt type is similar to that of *Avena sterilis*. He found that three non-Burt plants with the disjunction appeared in F_2 to one with the Burt form. Fraser also found linkage between the Burt disjunction type and the fully awned condition, 4.14 per cent of crossovers being found in 2,341 individuals. He states that the Burt oat used as parental material had the *A. sterilis* disjunction type, while the Sixty-Day had the usual *A. sativa* characters in all respects.

BASAL HAIRS

Basal pubescence or the hairs borne on the callus at the base of the oat floret has been given varying amounts of attention by different investigators.

Nilsson-Ehle (*90*) observed that certain oat varieties had long hairs on the callus, others had short hairs, while still other forms had few or no hairs. When a long-haired form was crossed with a short-haired form, the resulting recombination produced some individuals having no basal hairs and others having stouter hairs than either parent. The hairs of the rachilla were found to be inherited quite independently of the basal hairs.

Zade (*153*), in discussing the results obtained from a cross of *Avena fatua* by *Avena sativa*, states that F_1 was intermediate and that the F_2 showed the two parental and the intermediate types of basal hairs. The progeny segregated in a 1 : 2 : 1 ratio.

Trabut (*135*) makes use of the character of basal hairs in tracing the origin of cultivated forms from the wild oat species.

Etheridge (*33*) in reviewing the work of previous systematists states that the basal hairs frequently are employed by botanists, notably Hitchcock (*52*) and Britton and Brown (*11*), in characterizing Avena species. He states that Denaiffe and Sirodot (*26*) are the only authors who have made definite use of the basal hairs in classifying cultivated forms of *Avena*, although Böhmer (*10*), Broili (*12*), and Fruwirth (*38*) mentioned this character in discussing the morphology of the oat floret and distinguished types of basal hairs on the basis of differences in their form and frequency. In his classification of oats, Etheridge uses a modification of the systems of Broili and Fruwirth. Fischer (*35*), according to Etheridge, holds that the hairs on the base of the oat kernel are a mark of degeneration, and that they occur more often in the winter varieties than in others.

Surface (*127*), reporting on the cross *Avena fatua* × *Avena sativa*, variety Kherson, states that in F_1 basal pubescence was present and the base form was intermediate but more closely resembled that of the *sativa* parent. With regard to the F_1 of this cross he states that the lower floret is pubescent on the back but the upper is entirely glabrous. There is a fairly heavy tuft of hair at the sides of the base of the lower floret but none on the upper. Surface also found that there was correlation between the "wild" base and heavy pubescence on all sides of the upper floret. He also found that pubescence on all sides of the lower floret of the spikelet was correlated with the "wild" type of base.

Fruwirth (*39*) found that the basal hairs on the oat kernel are rather constant in breeding behavior, and that selections for nine years did not effect any change in the density or length of the basal hairs.

[13] WIGGANS, R. G. OP CIT.

Wilds [14] studied the inheritance of basal hairs in crosses of *Avena fatua* with cultivated varieties of *Avena sativa*. He found that the length of the basal hairs was determined by a single pair of genes, shortness being dominant. These genes segregated independently of the other kernel characters studied.

In addition to basal hairs, the kernels of the wild oat parent of these crosses have dorsal hairs. The factor which determines the presence of hairs on both the lower and upper florets is linked with the black color factors.

Love and Craig (*70*) crossed *Avena fatua* with *Avena sativa* variety Kherson. Their results were similar in many ways to those of Nilsson-Ehle (*91*) and Surface (*127*). They observed the intermediate F_1 type with basal hairs on either side but not on the back of the kernel. In F_2 they found the sativalike base dominant, or at least partially so, to the type of base of the wild oat. They also found some linkage between the wild type of base of the wild oat and pubescence, and that the yellow form appeared to carry an inhibitor for pubescence.

Wiggans [15] observed the behavior of the basal hairs in the cross Red Texas × Swedish Select. The F_1 kernels had only a few basal hairs which were approximately the same length as the basal hairs of the Red Texas parent. The F_2 plants were grouped into two classes, hairy and glabrous, although within the first group there was a wide variation in the number of hairs. There was not a great amount of variation in the length of hairs, although a few individuals appeared with much shorter hairs than the Red Texas parent.

The results obtained in F_2 and F_3 may be explained on a two-factor hypothesis.

Fraser (*37*), in describing the Burt × Sixty-Day cross, states that a strong linkage exists between the fully awned condition and medium long hairs at the base of the grain. In 2,341 individuals there was about 5 per cent of crossovers. He found short basal hairs or no basal hairs to be dominant to medium long basal hairs. In F_2 he obtained a ratio of three of the former to one of the latter.

AWNS

The awn is an extension of the midrib of the lemma and usually arises at a point slightly above the middle of the dorsal surface. In most wild species of oats the lemmas of all the florets are awned, the awns being stout and long with the lower portion twisted in a dextrorse or clockwise direction and the upper portion bent over. In all cultivated varieties of *Avena sativa* the awn usually occurs only on the lower lemma, if at all, and usually is small in size. In some varieties derived from *A. byzantina* awns occur occasionally on both florets and sometimes they are twisted or geniculate.

Raum (*108*) considered the presence of awns a very important character in oats, although influenced by climatic conditions and particularly by the rainfall. According to this investigator the weight of the floret and also of the lemma and of the caryopsis increased approximately 10 per cent with the presence of the awn. Completely awnless varieties of oats, however, were not found.

Norton (*99*) found that awned and awnless oats when crossed gave a partially awned type in F_1, which in F_2 split up in a ratio of 1 awned to 2 partially awned to 1 awnless.

Fernekess (*34*) observed that the presence of awns was associated with heavier kernel weight in oats.

Zade (*153*), on crossing a cultivated variety of *Avena sativa* with *Avena fatua*, found in F_1 that the lower floret of the spikelet was awned, which showed presence of the strong awn to be dominant, to some extent at least, over its absence. In the F_2 he observed a ratio of 1 awned to 2 partially awned to 1 awnless.

Nilsson-Ehle (*95*) observed in a cross between a black, strongly awned and a white awnless oat that the F_1 showed the awn on the lower floret of the spikelet. In F_2 the ratio obtained was 1 awned to 2 partially awned to 1 awnless. He found awns to be produced more commonly by black and by white kernels than by yellow ones. He attributed the failure of yellow kernels to produce awns to an inhibitor carried by kernels of that color. He also observed that environmental conditions greatly influence the production of awns in cultivated varieties. He stated that plants having the gene for producing awns may fail to show the awns because of environmental conditions.

Trabut (*135*) in tracing a series of forms between the wild *Avena sterilis* and its cultivated derivatives observed a gradual reduction in the number of awns per spikelet and in the strength of the awns.

[14] WILDS, G. J. OP. CIT.

[15] WIGGANS, R. G. OP. CIT.

Etheridge (*33*) in his classification of oat varieties made use of the awn as a character of secondary importance. He states that the geniculate awns appear abundantly only in a few half-wild varieties, but in such cases they are recognized as a distinguishing character. It is not believed by the present writers that this statement of Etheridge is fully justified, as some of our most valuable cultivated varieties, such as Swedish Select, normally have this type of awn.

Etheridge (*33*) found that in respect to presence or absence of awns, together with their form, the varieties under study have remained constant. In his review of the work of different authors he states that Körnicke and Werner (*64*) made the primary division of the principal groups of oats according to the number of awns per spikelet, that Denaiffe and Sirodot (*26*) used the awn as a distinction between varieties, that Atterberg (*5*), Nilsson (*89*), and Böhmer (*10*) made no use of the awn, and that Broili (*12*) believed the awn to be of little or no value in classifying oat varieties.

Surface (*127*), in crossing *Avena fatua* with *Avena sativa*, variety Kherson, found the F_1 to bear awns on only the lower floret and that the second floret of the spikelet was never awned. In F_2 he found stout awns on the lower floret and awns on the upper floret, both correlated with the *fatua* type of base. He found a slightly greater proportion of the yellow-kerneled plants than of the other colors which were awnless but did not consider the difference significant. According to Surface there did not seem to be any marked correlation between yellow color and absence of awn in this cross.

Love and Fraser (*69*) made a cross between Burt, a weak-awned [16] variety, and an awnless strain of Sixty-Day and observed that the F_1 plants were almost awnless. In F_2 a ratio of approximately 2 awned to 1 awnless plant was found. In F_3 the fully awned forms bred as pure recessives, the partially awned plants bred in the ratio of 3 awnless to 1 awned, and certain awnless F_2 plants apparently were heterozygous as they produced awns in F_3. Love and Fraser do not believe the yellow color in Burt carries the inhibitor for awns as does the yellow color in Kherson. According to these authors it appears that the yellow color in Sixty-Day carries an inhibitor for awn development.

In the cross Red Texas × Sixty-Day the same authors found only 1.3 per cent of awns in F_1. The awnlessness of the Sixty-Day parent apparently was dominant in F_1 over the weak-awned type. In F_2 an approximation of the 1: 2: 1 ratio was observed. The fully awned type was found to breed as a pure recessive, partially awned types were shown to be heterozygous, and awnless F_2 plants broke up in F_3, showing that not all awnless F_2 plants can be considered as pure dominants. Love and Fraser state that weak awns and awnlessness in oats probably are due to a 1-factor difference. Sixty-Day may carry an inhibitor for awn development linked with the yellow color, but Burt evidently does not carry such an inhibitor, as awned yellow Burt types are found in numbers.

In a cross of the strong-awned *Avena fatua* with the awnless Sixty-Day the same authors found F_1 to be intermediate. In F_2, 133 awnless, 215 intermediate, and 112 plants exhibiting the "wild" type were found. These authors state that in the Burt variety, which they consider a *sterilis* type, the fully awned condition was correlated with the Burt type of disjunction and midlength basal hairs. They also state that 2-awned spikelets are found only in fully awned panicles.

Wilds [17] studied the inheritance of awn type in crosses of *Avena fatua* with Tartar King and Sixty-Day. The strong awn was found recessive to the awn of intermediate type (awnless) and partially awned plants were considered as dominants.

Love and Craig (*70*) reported that, in a cross of *Avena fatua* and *Avena sativa*, variety Sixty-Day, the F_1 was intermediate and that there was some relation between the yellow color and the absence of awns. In another paper (*71*) they state that for the "weak" awn the fully awned condition is recessive and the character seems to occur in a simple 1: 2: 1 ratio.

Meunissier (*77*) considers that the awn is a fluctuating character. He states that there are strains of oats mostly much awned, others which have very few awns, and still others which are entirely without awns. Absence of the awn appears to be clearly a recessive character. He states that the twisting of the awn is sinistrorse (in a spiral to the left).

[16] The "weak" awn class of Love and Fraser includes the "nontwisted" awn class described in the present paper.

[17] WILDS, G. J. OP. CIT.

Wiggans[18] studied the behavior of the awn character in the cross Red Texas × Swedish Select. The F_1 spikelets possessed only one awn and this was slightly twisted and bent, a typical intermediate condition. The F_2 plants were classified in regard to awns per spikelet as (1) one strong awn (2) one intermediate awn (3) one weak awn, and (4) two weak awns. The last two classes proved to be the same in their breeding behavior and should be considered as one class. If this is done a close approximation to the following ratio is obtained: 1 (one strong awn) : 2 (one intermediate awn) : 1 (one or two weak awns). These results indicate that one pair of factors determine the kind of awns in this particular cross, although both parents contain at least one other factor for awning.

It was found that yellow plants practically always had either one weak awn or two weak awns on each spikelet and that the plants classified as whites generally had only one awn to the spikelet and this one was strong in the majority of cases. There are indications of a strong linkage between the yellow color and the weak-awned condition. The linkage between white color and strong-awned spikelets was not so strong as that between yellow color and weak awns but is significant.

In the cross Burt × Sixty-Day Fraser (*37*) found nearly complete dominance of the awnless condition. According to Fraser both parents carry the factor for awning, but this factor was prevented from operating in Sixty-Day by an inhibitor linked with yellow color. In the first generation the production of awned plants is dependent on the extent of dominance which this inhibitor displays, which in turn probably is dependent on environmental factors. In F_2, awnless, partly awned, and fully awned plants are produced approximately in the ratio of 1 : 2 : 1, the ratio of plants not fully awned to plants fully awned being close to 3 : 1. The fully awned plants when tested in F_3 proved to be pure recessives. Nearly all partly awned plants were heterozygous and gave ratios of approximately 3 plants not fully awned to 1 fully awned. The awnless F_2 plants were of two kinds, those breeding true, or practically so, and those which segregated in a manner similar to an F_1 plant.

Zhegalov (*160*) has reported the results of a number of species crossed in oats and discusses the inheritance of awns and other characters in these crosses.

Marquand (*75*) found that the percentage of awned spikelets in panicles taken from unselected varieties is constant on the whole, and unaffected by external conditions though probably dependent upon multiple factors.

LEMMA COLOR

In this review it is understood that all references made by the various authors to color of glumes, kernels, and grain were intended to apply to the floret and more definitely to the lemma or flowering glumes.

Körnicke and Werner (*64*) in their classification of oats used lemma color to distinguish the main groups of varieties of *Avena sativa* and *Avena orientalis*.

Von Tschermak (*136*) found that black color in the glumes was dominant over the light or yellowish color.

Wilson (*151*) crossed Black Tartarian oats with Goldfinder, a white oat. The F_1 plants had rich brown grains. In F_2, black, brown, yellow, and white kernels could be distinguished. By including the blacks and browns in a dark-kerneled class and the yellows and whites in a light-kerneled class, a ratio of 2.99 of the former to 1 of the latter was obtained. Other crosses between Black Tartarian and white-seeded varieties gave results in F_2 which clearly indicated the dominance of dark-kernel color.

Norton (*99*) found that black and white oats when crossed gave a brown hybrid in F_1, but in F_2 they produced a ratio of 1 black: 2 brown: 1 white. In succeeding generations the extracted black and the extracted white types bred true.

Roberts and Freeman (*114*) studied an apparent genetic alteration of the color type of Red Texas oats from red to black under Kansas conditions but found that close-pollinated plants of each sort yielded seed which came true, indicating no sporting of one variation from the other.

Nilsson-Ehle (*91*) noted a slight variation in the lemma colors of oats as the result of environment, although he believed that in the main they tend to breed true. He found the range of variation in dark-colored florets to be from black to brown or brown to black. Crosses of the following types were made: Black × white, yellow × white, gray × white, black × yellow. In crossing black and white oats he found

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that black was dominant over white and that there were two factors for dark color. The presence of one of these factors produced gray, while when both were present the kernel was black. In the absence of both color factors white kernels resulted.

Nilsson-Ehle (*92*) described cases of the spontaneous omission of the color factor in oats, giving rise to white and gray kernel types in pure-line material of black varieties.

Zade (*154*) in his studies of inheritance in *Avena fatua* observed that the kernel colors tended to breed true.

Thatcher (*129*) found as the result of experiments in crossing oats that black hull was dominant over white hull.

Nilsson-Ehle (*95*) showed that there is a very definite linkage of the factor which inhibits awning and the factor for yellow color.

Etheridge (*33*) states that the color of the lemma when ripe has been accorded various degrees of importance in classification by other investigators. In some cases Etheridge used color as the basis for separation of the principal groups. He states that it is the most conspicuous character of the oat grain, that it is certainly inherited, and therefore is of particular use in identification and description. He points out that while the color is affected by changes in environment and may pass into different tones of the same general hue, it does not transgress the limits of the type. One must not attempt to make fine subdivisions of color, for the distinctions may be lost by variation within the type. In his review of the work of previous investigators Etheridge states that Nilsson (*89*) Denaiffe and Sirodot (*26*), and Dufour and Dassonville (*27*) all used color in making varietal distinctions. He also states that Böhmer (*9*) used color as a final means of distinguishing varieties, while Fruwirth (*38*) believed color of little importance, and Atterberg (*5*) mentions it only as a descriptive character.

Surface (*127*) presents the results obtained from a cross of *Avena fatua* with *Avena sativa*, variety Kherson. He states that the wild parent has a dark brown or almost black lemma color, while the Kherson has a yellow color. He found F_1 to be intermediate in color between the two parents and of a lighter brown color than the wild parent. In F_2 and F_3 it was shown that the results could be explained on the basis of the presence of three separate factors, black, gray, and yellow, each of which is allelomorphic to white.

Gaines (*40*) has studied the inheritance of lemma color in oats in 10 different crosses. The parental combinations used by Gaines in studying this character were as follows: (1) Storm King × Black Tartarian, (2) Regenerated Swedish Select × Black Tartarian, (3) Black (Cereal Investigations No. 290) × Regenerated Swedish Select, (4) Black × Sixty-Day, (5) Black × Palouse Wonder, (6) Black × Hull-less, (7) Sixty-Day × Chinese Hull-less, (8) Black Tartarian × Hull-less, (9) Canadian × Chinese Hull-less, and (10) Storm King × Chinese Hull-less.

In a total of 29,730 F_2 plants a ratio of 24.9 per cent of plants with white florets to 75.1 per cent with black florets was obtained. Gaines believes that the factor for lack of hulls in oats which causes the floral glumes to expand, elongate, and remain widely spread at maturity (the characters that distinguish naked varieties), inhibits the development of the dark color in the floral glumes, for in all the crosses not a single true naked plant developed black floral glumes. If it had not been for the brownish coloring of the palea the naked hybrids which bred like black oats when crossed with white-hulled varieties could not have been distinguished from those that were genetically white.

Love and Fraser (*69*) observed in crosses of Burt with Sixty-Day and with other varieties that the yellow color of Burt apparently carries no inhibitor for awns, but that the yellow color of Sixty-Day apparently carries this inhibitor in a manner similar to Kherson, as described by Surface (*127*).

Wilds [19] studied crosses of the wild oat, *Avena fatua*, with Tartar King and Sixty-Day, and concluded that the genes for color of the flowering glumes segregate independently of each other, each being allelomorphic to white or to its own absence. In the cross of the wild oat × Tartar King (white) the F_2 ratio obtained was very close to the expected 12 blacks and browns : 3 grays : 1 white. In the cross of the wild oat × Sixty-Day (yellow) an F_2 ratio of 12 blacks : 3 grays : 1 yellow was observed.

The ratios obtained in these crosses indicated a negative correlation between yellow lemma color and *fatua* articulation, between yellow color and awns, between yellow color and basal lemma pubescence, and between yellow color and dorsal pubescence.

Caporn (*14*) studied the inheritance of kernel color in crosses between

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Avena nuda, said to be impure as regards color, and the white-husked varieties Thousand Dollar and Ligowa, which were a mixture of grays and whites. The presence of grays demonstrated, however, the dominance of the gray color whenever the cross gray × white actually occurred.

In another cross, Nubian Black × *Avena nuda*, the F_1 color was a bright brown sometimes overlaid with a faint grayish flush. Here the F_1 also may vary because the black parent is genetically really made up of at least three different kinds of blacks, represented zygotically by the formulæ BB B′B′ GG, BB B′B′ gg, and BB b′b′ gg, where B and B′ are factors for blackness and G for gray color. In F_2 a ratio of approximately 3 gray to 1 white was observed. There was no linkage or repulsion of gray or brown color with tight paleas.

Caporn reports in another paper (*15*) on a cross between Mesdag, a variety with dark-brown florets and distinct affinities with *Avena fatua*, and Hopetown, a white-glumed variety. The F_1 florets were somewhat lighter brown than those of Mesdag. No data on the inheritance of color in F_2 are given.

Love and Craig (*70*) present data on a cross of *Avena fatua* and *Avena sativa*, variety Sixty-Day. The result obtained in this cross corresponds very closely with that obtained by Surface (*127*). They assumed that *Avena fatua* carries color genes for black, gray, and yellow, and that Sixty-Day has the gene for yellow. They found a strong indication of an inhibitory factor or factors which prevent not only awn development but also the wild form of lemma base and pubescence in combination with yellow color of the lemma.

Love and Craig (*71*) found that in crosses between the Sixty-Day oat and the wild *Avena fatua* the yellow color of the Sixty-Day inhibits the production of well-developed awns and pubescence on the glumes. These crosses also have shown that different types are found in *A. fatua*. One sort when crossed with the White Tartar King gives 15 plants with lemmas pubescent to 1 nonpubescent in the second generation, while another type produces a ratio of 3 pubescent to 1 nonpubescent. Two forms of black oats classed as the same variety produced plants with white florets in the second generation in the ratio of 15 black to 1 nonblack.

Meunissier (*77*) states that white glume color is recessive to other colors.

Pridham (*106*) quotes A. E. V. Richardson, of Australia, as having mentioned that in oats all the different tints of kernel color appear to be Mendelian dominants to colorless or white.

Wiggans[20] studied the inheritance of kernel color in the Red Texas × Swedish Select cross. The color of the F_1 florets was red, although a somewhat lighter red than that of the red parent grown under the same conditions. Floret color, as developed under greenhouse conditions, proved to be a difficult character to work with. Four types were evident in F_2, red, gray, white, and yellow, although accurate classification was practically impossible. The data indicate that there is more than one pair of factors which determine color. The factor for red is the dominant one.

Fraser (*37*), in crossing Burt (red) with Sixty-Day (yellow), found F_1 to be intermediate in color. In F_2 difficulties in classification were experienced because of the gradation of colors and the influence of environmental factors. An approximate ratio of 48 reds : 15 yellows : 1 white was observed in F_2. Fraser considers that Burt carries two color factors, red and yellow, while Sixty-Day has only the factor for yellow.

According to Fraser (*37*) the genetic formula for floret color in the Burt variety would be RRYYy′y′. The variety Sixty-Day would have the genetic formula rryyY′Y′. He states that the results in the F_3 generation bear out this theory in a general way. He believed that because of the yellow color factor in the Burt variety which carries no inhibitor for awns, the inhibitory effect of the Sixty-Day factor was obscured. Fraser considered the few brown florets which appeared in the course of his studies to be the result either of mutation or of reversion.

Wakabayashi (*140*) reported a cross between *Avena sterilis*, variety Red Rustproof, and *Avena sativa orientalis*, variety Black Tartarian. He found the black color of Black Tartarian to be a simple Mendelian dominant, and believed that there was some linkage between white color and susceptibility to smut.

PRELIMINARY OBSERVATIONS

Apparently one of the first persons to recognize the variability of the Burt oat was J. B. Norton, formerly engaged in oat breeding in the United States Department of Agriculture. He

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pointed out in 1907 the unusual position of the variety. Wilson G. Shelley, formerly in charge of the experiments of the United States Office of Cereal Investigations at the Akron Field Station, Akron, Colo., observed in 1910 that Burt was a promising early variety and recorded in his field notebook that the kernels of the variety lacked uniformity in color.

In 1916 one of the writers (Parker) observed (*100*) that the Burt oat had potential value because of its resistance to rust. Several strains of Burt were being grown at the Kansas Agricultural Experiment Station when he took charge of the crop improvement project in 1918. A special effort was made to obtain additional strains from all possible sources. Pedigreed selections were made from several strains, and studies of the smut resistance of Burt and other varieties were started. The marked variability of the Burt variety, clearly indicated by the earlier studies of rust resistance, was observed to be very evident with respect to plant and kernel characters.

Preliminary experiments to determine the nature of the variability existing in the Burt oat were initiated by the senior writer at the Akron (Colo.) Field Station in 1919, at the suggestion of T. R. Stanton. These experiments were started with the Burt oat selection, Cereal Investigations No. 293–6–09, made by Wilson G. Shelley when he was at the Akron Field Station. This selection is now named Colburt (C. I No. 2019). The original plan was to use the plant as the unit for study. The kernels were spaced 6 inches apart, 25 kernels to the row, in rows approximately 12 inches apart. Approximately 600 plants were produced from the sowing of 1,000 kernels, and of this number 75 were retained for the study of variation. These plants were threshed by hand in the spring of 1920. General notes were recorded on the plant characters and detailed notes were taken on the floret characters of each plant. The descriptive notes on floret characters may be summarized as follows:

1. In color the florets of some plants were more variable than those of others.

2. The florets from some plants were uniformly dark brown or black, while those from others were uniformly light brown.

3. In some plants the florets were uniformly large, and in many cases the large kernels were very dark in color.

4. The awns borne by the florets of a single plant varied in character. The twisted awn was frequently observed. No plants were found with all of the lower florets of the spikelets bearing awns, although many awnless plants were observed.

No further study was made of this material.

MORPHOLOGY OF THE OAT SPIKELET

A brief discussion of the oat spikelet is given here to make clear the genetic discussion which follows.

The spikelet is borne on the thickened end of the slender, drooping pedicel which terminates the panicle branch. Each spikelet usually contains two or more florets, though one-flowered spikelets occur rarely. No oat varieties are known which produce one, two, or three florets per spikelet, exclusively. The lower two florets usually are perfect, while the third, if present, often is staminate or imperfect. The first floret is the largest and contains the larger kernel or caryopsis.

The two lower glumes, or empty glumes, are somewhat unequal, lanceolate, acute, boat shaped, spreading, glabrous, membranous, and usually persistent. Both usually exceed the lemma or flowering glume in length, except in naked oats.

The rachilla or axis of the spikelet bears all of the florets and connects the spikelet with its supporting pedicel. In some species, as *Avena nuda* and *A. strigosa*, the rachilla segments are elongated and narrowly clavate, while in other species, as *A. sterilis*, *A. fatua*, and many of their cultivated derivatives, the segments usually are shorter and more thickened. Zade (*156*) states that the greatest difference between wild and cultivated oat species is their method of separation from the pedicel.

The floret is composed of the lemma, the palea, and the organs of reproduction, namely, the ovary with its bifid style, plumose stigma, and the three stamens.

The lemma or flowering glume is the lower of the two bracts or scales which form the envelope of the kernel. It is slightly shorter and much firmer in texture than the empty glume. It is ovate-lanceolate or boat shaped, with the scabrous apex bifid or entire. The veins of the lemma and glume appear as slender, riblike striations. In some wild forms the veins of the lemma extend beyond its apex as teeth or awn points and are used as characters in distinguishing species. The number of the nerves is variable, usually ranging from 7 to 11 in cultivated varieties. The base of the

lemma may be extended into a swollen callosity, commonly called the callus.

The dorsal surface of the lemma may be either hairy or glabrous, characters much used in separating oat species. Most wild species of oats are characterized by hairiness of the callus, lemma, and rachilla. The callus, a somewhat swollen, thickened and hardened projection at the base of the lemma, often bears more or less conspicuous bristles, usually termed basal hairs. The presence of these hairs may be observed readily without magnification.

The awn of oats is an extension of the midrib of the lemma, usually arising at a point slightly above the middle of the dorsal surface. In *Avena fatua*, *A. sterilis*, and various other wild species all lemmas are awned. In these the awns usually are stout and long and the basal portion is twisted dextrorsely or in a clockwise direction. That part of the awn above the twisted portion usually is bent or geniculate. In most cultivated varieties derived from *A. fatua* and *A. sterilis* the awn when present occurs only on the lower kernel of the spikelet and then it may be diminutive in size. In some cultivated varieties it occurs only rarely, even on the lower lemma. In varieties of *A. byzantina* awns occasionally occur on both kernels and sometimes they are twisted or geniculate.

Trabut (*155*) observed a gradual reduction in the number and size of the awns in passing from the wild *Avena sterilis* to the cultivated strains represented by *A. byzantina*. Some authors believe the occurrence of numerous twisted and geniculate awns in cultivated oat varieties to be an indication of degeneracy resulting from an unfavorable environment.

The palea or palet, the inner or upper bract or scale of the floret, is a thin parchmentlike scale, the margins of which usually interlock with those of the lemma. The palet may be toothed at the apex. The tightness with which the lemma and palea clasp the caryopsis is an important character in oat classification. In *A. nuda* they inclose the caryopsis rather loosely, while in most hulled varieties the caryopsis is firmly inclosed.

The oat caryopsis is narrowly oblong or spindle shaped, deeply furrowed on the ventral surface, and usually covered with fine hairs, especially at the upper end. The caryopsis usually has no characters of value for classification purposes.

SPIKELET DISARTICULATION

The separation of the lower floret of the oat spikelet from the rachilla or axis of the spikelet is here termed spikelet disarticulation, in contrast to floret disjunction or the separation of the florets of the spikelet from each other. Few experiments have been conducted on the histology of the oat spikelet, and as a result the exact structure of the rachilla is not well understood.

In the wild species, *Avena fatua* and *A. sterilis*, and in most of the cultivated varieties the basal segment of the rachilla usually is short and thickened. Apparently, the basal segment of the rachilla and the projecting basal callus of the lower floret are united obliquely in the lateral plane, the callus being dorsal and the rachilla ventral. In the two wild species named, spikelet disarticulation takes place by means of an oblique abscission layer, apparently located in the cleavage plane between the basal rachilla segment and the callus of the lower floret. It is possible that a true articulation between the base of the lower lemma and the apex of its supporting rachilla segment exists above this abscission layer, and that this abscission layer is formed in the tissue of the rachilla segment itself, but this is very improbable. Separation at this layer in that case would leave a portion of the basal rachilla segment attached to the lower floret.

In the present paper it is assumed that the abscission layer is formed at the base of the callus of the lemma, and that below this abscission layer the tissue is rachilla, while above this layer it is lemma. In *Avena sterilis*, *A. fatua*, and some of their cultivated derivatives the separation at this definite oblique abscission layer leaves a well-defined deep oval cavity, commonly called the scar, or "sucker-mouth," in the face of the callus. A corresponding but shallower depression remains in the face of the disjoined basal segment of the rachilla.

Zade (*156*) states that connection between these two parts, the callus and the rachilla segment, is only at the periphery in the wild species, while in the cultivated oat, *A. sativa*, the central portion also is solid, being filled with a parenchymatous tissue. The writers believe his observations probably are correct for conditions at maturity, but that in fresh, immature plants the union of the rachilla and callus is solid both in wild species and their cultivated derivatives. The cav-

ity apparently is evident only in mature or nearly mature specimens. In many fresh, immature specimens both of wild and cultivated oats the writers have observed no hollow or scar in the callus or the basal segment of the rachilla when these organs are forcibly disjoined.

In the present study the different ways by which spikelet disarticulation takes place were classified as resulting from (1) abscission when the method of spikelet separation was that characteristic of the wild *Avena fatua* or *A. sterilis*, that is, resulting in a pronounced cavity or scar in the base of the lemma; (2) fracture when the method of separation was that most characteristic of the cultivated varieties of *A. sativa*, that is, resulting in a roughened tissue with no observable cavity or scar at the base of the lemma; and (3) semi-abscission when the method of separation was to some extent intermediate between the two, apparently resulting partly from abscission and partly from fracture, and leaving only a slight and often poorly developed cavity or scar in the base of the lemma. These three kinds of disarticulation are shown in Plate 1, A to C.

FLORET DISJUNCTION

The florets of an oat spikelet are connected by the clavate segments of the rachilla. The articulation at the juncture of two segments is not very evident, owing to the structure of the spikelet. The base of the lemma of each floret is attached to the enlarged apex of the rachilla segment which bears it and entirely surrounds the slender base of the segment which bears the next higher floret. This latter segment, therefore, appears to grow out from the basal tissue of the inrolled lemma next below (Pl. 1, D). The manner of separation of the florets from one another, here termed floret disjunction, differs in different species.

The rachilla segments usually are narrowly clavate in shape and variously flattened, rounded, or furrowed. They usually are 1.5 to 3.5 mm. long, except in *Avena nuda*, where they are extremely elongated. In the wild species they often are clothed by stiff hairs. The number and character of these hairs are much used in differentiating between wild and cultivated forms.

In some species, as *Avena fatua* and its derivative *A. sativa*, disjunction of the second and additional florets usually takes place by disarticulation at the apex of the rachilla segment. In such cases the rachilla segment remains attached ventrally at the base of the next lower floret of the spikelet. The attachment of the rachilla segment to the base of the second and subsequent florets is very firm in *A. sterilis* and its derivative *A. byzantina*. The florets of the spikelet often remain attached together during threshing. When forcibly separated, the segment breaks near its base, as pointed out above. But in *A. sativa* the separation by disarticulation at the base of the floret usually takes place very readily.

In the present study it was observed that in some cases the segment breaks across near the middle or even splits irregularly lengthwise.

Floret disjunction in this study is described in terms of the nature of the disjunction of the supporting rachilla segment. The term (1) disarticulation is used when the segment disarticulates from its floret, as in *Avena fatua*; (2) the term basifracture when disjunction is by fracture at the base and it remains attached to the floret, as in *A. sterilis;* and (3) the term heterofracture when it fractures irregularly in the middle and the disjunction can not be classified definitely. Plate 1, D to F, shows these three different types of floret disjunction

BASAL HAIRS

The surface of the lemma may be either hairy or glabrous, characters much used in separating oat species. Most wild species of oats are characterized by hairiness of the lemma, callus, and rachilla. The callus often bears more or less conspicuous bristles, usually termed basal hairs. The presence of these hairs may be observed readily without magnification.

The classification of basal hairs in the present paper conforms somewhat to that of Zade (*156*). He classed them as long, intermediate, and short. The writers have discussed them as (1) abundant long, (2) abundant midlength, (3) few, disregarding length, and (4) absent.

The abundant long class of the writers is practically identical with the long class of Zade. The abundant midlength class includes most of those he described as intermediate. In addition, the writers included in this second class a few kernels bearing hairs which though rather short were very abundant. Some of these kernels doubtless would have been put in Zade's short class. The writers' "few" class was in reality a sort of catchall. It included all kernels that were only

A to C.—Spikelet disarticulation, or separation of the lower floret from the basal segment of the rachilla. A.—Disarticulation by abscission, the method occurring commonly in the wild oat species *Avena fatua* and *A. sterilis*, and in some strains of the Burt oat. B.—Disarticulation by semiabscission, more or less intermediate between A and C, apparently resulting partly from abscission and partly from fracture, and leaving only a slight and often poorly developed cavity in the base of the lemma. C.—Disarticulation by fracture. The method of separation most characteristic of the cultivated varieties of *Avena sativa*, resulting in a rough, fractured tissue with no observable cavity at the base of the lemma.

D to F.—Floret disjunction, or separation of the second floret from the first or lower floret. D.—Disjunction by disarticulation. The second floret disjoins by disarticulation of the second rachilla segment from the base of the second floret, the common method in the wild species *Avena fatua* and the cultivated varieties of its derivative, *A. sativa*. E.—Disjunction by heterofracture. The rachilla segment breaks transversely somewhere in the middle portion, or may break both transversely and longitudinally, the latter splitting being very diverse. F.—Disjunction by basifracture. The common method of separation in the wild *Avena sterilis* and the cultivated varieties of its derivative, *A. byzantina*, the rachilla segment breaking at or near its base and remaining firmly attached to the base of the floret.

sparsely hairy whether the hairs were long, midlength, or short. A few kernels with hairs abundant, but so very short that they could not be placed in the abundant midlength class, were also thrown into the "few" class.

Many different classifications of the basal hairs in the oat kernel have been used, and nearly all such classifications have objectionable features. All classifications must be more or less arbitrary, as they are based on number or length of these bristles. A few authors have used a combination of these two characters. Although realized to have objectionable features, the writers believe the following proposed classification might have been followed with profit:

1. Long.
   Many.
   Few.
2. Midlength.
   Many.
   Few.
3. Short.
   Many.
   Few.
4. Absent.

In describing large numbers of oat kernels the writers find all of these classes and subclasses to exist. The different classes of basal hairs used in this study are shown in Plate 2.

AWNS

Various authors have used different terms for designating the different kinds of awns. Here again any classification must of necessity be an arbitrary one and as such is subject to differences of opinion. The terms strong, twisted, geniculate, and weak have been rather loosely used by one author in describing the awn of the oat. Another author has designated different awn conditions by the terms strong, intermediate, weak, and awnless. In describing the material on which data are presented in this paper the terms (1) twisted; (2) nontwisted, long (over 15 mm. in length); (3) nontwisted, short (less than 15 mm. in length); and (4) absent have been used.

The twisted awns usually are associated with the wild forms. These awns often are strongly kneed or geniculate. The percentage of the length of the awn which is twisted varies. In some cases where the twisting is less pronounced, and only one or two twists occur, the bending is too slight to be termed kneed, although bending apparently is very closely associated with twisting. Of the nontwisted awns the long awn may be fully as long as the twisted one but it has no twisting at its base and hence practically always lacks the dark color associated with the twisted base. The nontwisted, short awns are somewhat more variable than the other awn classes discussed. They are always slender, 15 mm. or less in length, grading downward to mere bristlelike appendages, sometimes more like hairs than awns. In kernels having no trace of awns the awn is said to be absent. The various oat awns are shown in Plate 3.

LEMMA COLOR

The oat lemma is of various colors. The principal ones recognized in previous descriptions have been black, gray, red, yellow, and white. In the present classification many kernels which were not dark enough to be called black but too dark to be termed either gray or red are called brown. A few authors previously have recognized brown as a kernel color but generally have considered it analogous to black.

In the present paper the lemmas were classified according to color as follows:

Black, dark brown, light brown, red, variegated, yellow, white. The colors of the lemmas in Burt are shown in Plates 4 to 6, inclusive. The florets with so-called variegated lemmas proved very diverse when their progeny were grown and this color subdivision was abandoned.

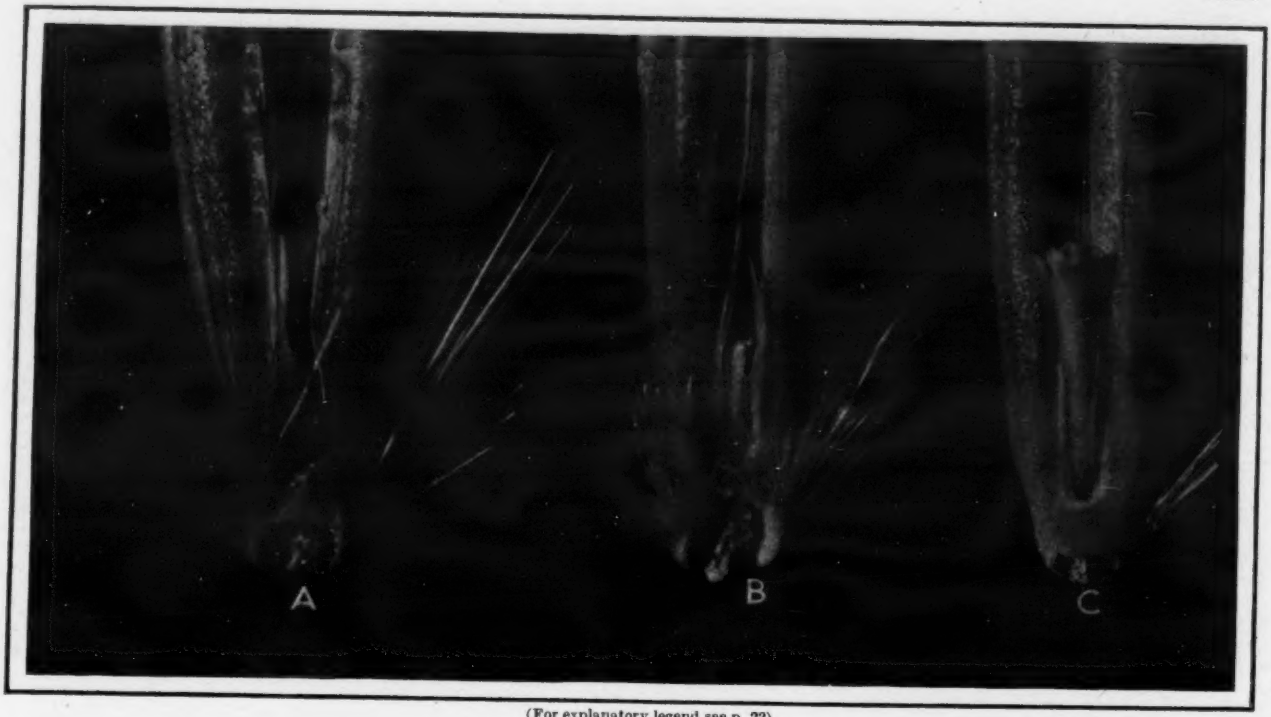
EXPERIMENTAL MATERIAL

In 1920 bulk lots of nine different strains of the Burt oat growing in the crop improvement nursery of the agronomy department at the Kansas Agricultural Experiment Station were chosen for the variability studies. This material showed considerable variation not only among the different strains but within each of the strains, and was exceptionally well suited for such a study. The strains used were Kansas Nos. 5020, 5211, 5219, 5022, 6004, 6052, 6076, 6090, and 6094. The accession records on file at the depart-

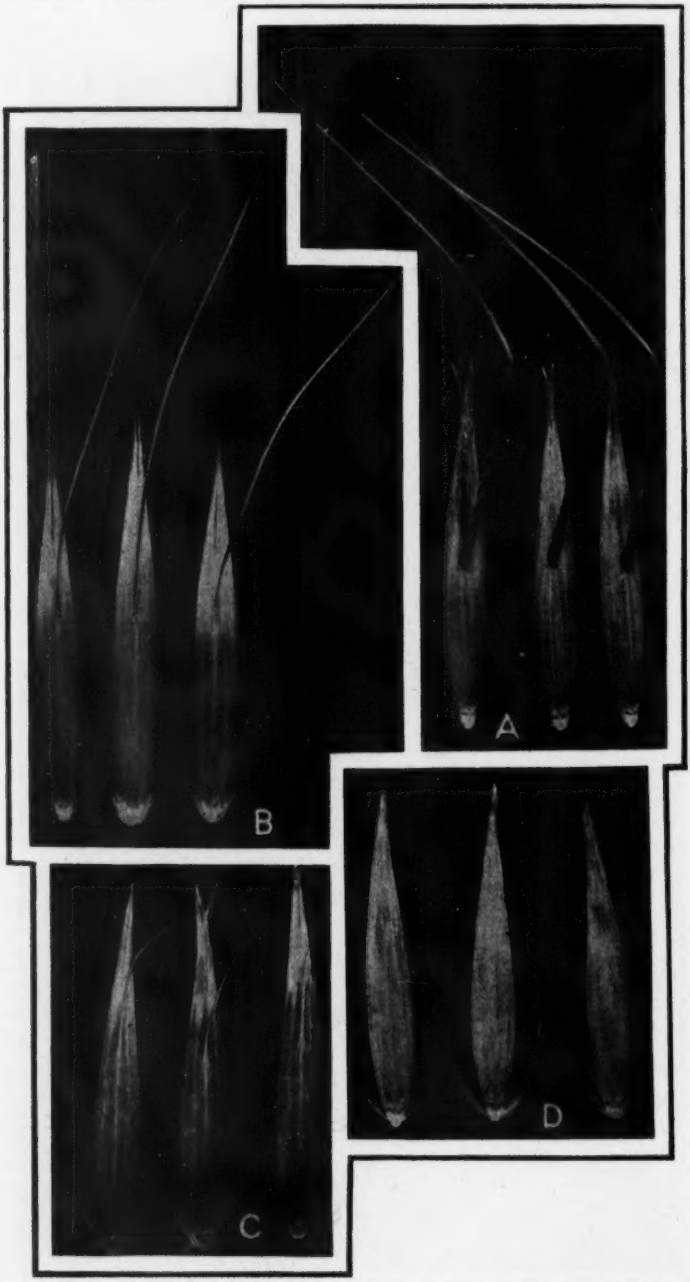
EXPLANATORY LEGEND FOR PLATE 2

A.—Abundant long basal hairs, characteristic of many wild oats. B.—Abundant midlength basal hairs, a condition somewhat intermediate between wild and cultivated varieties. C.—Few basal hairs. In nearly all cases these hairs are short but rarely kernels are found bearing only a few long hairs.

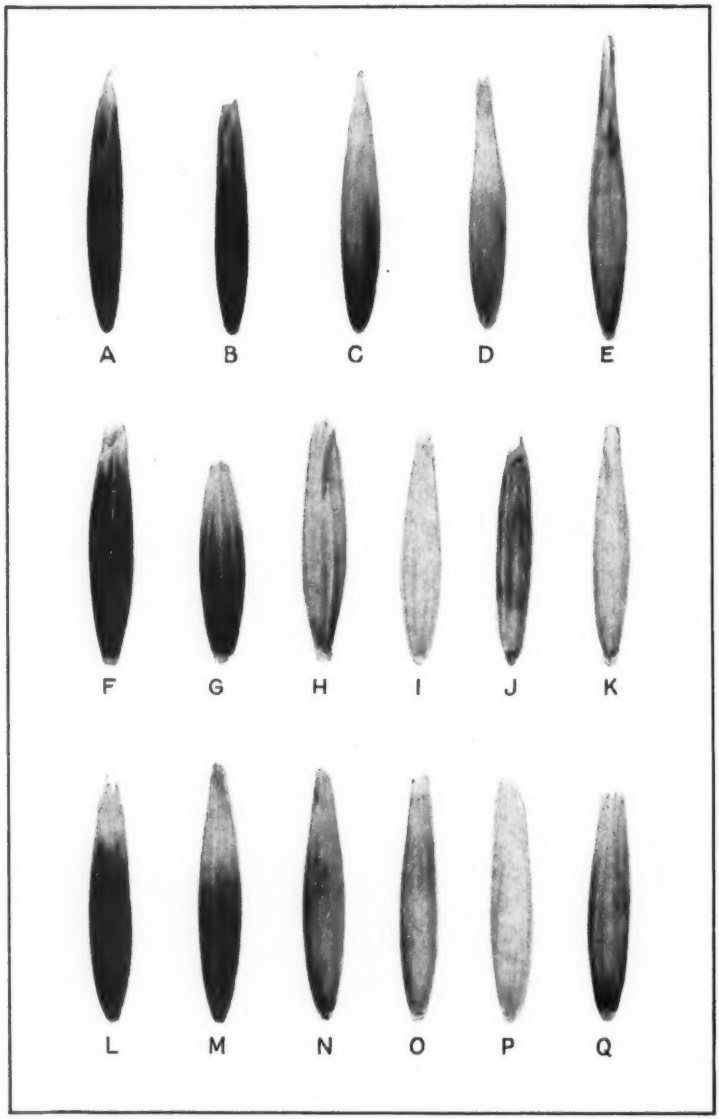
(For explanatory legend see p. 22)



(For explanatory legend see p. 22)



A.—Twisted awns. These awns from Kansas No. 5211 are long, stout, and strongly geniculate with a strong and evident twisting of the basal portion. B.—Nontwisted long awns from Kansas No. 6000. C.—Nontwisted short awns from Kansas No. 5220, varying from a mere point to 15 mm. in length. D.—Awnless condition, from Kansas No. 5211.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ment of agronomy of the Kansas Agricultural Experiment Station give the following histories and descriptions for these strains of Burt oats:

Kansas No. 5020 (Cereal Investigations No. 293) was obtained in 1904 from the cooperative field station of the United States Department of Agriculture and the Kansas Agricultural Experiment Station, at McPherson, Kans. The description of this variety as received at Manhattan was "gray and brown oats of good grade." This strain has been grown in the crop improvement nursery at Manhattan since 1911. In 1919 the general description [21] given the strain was "awnless, smooth and pubescent grains, light yellow to brown in color and with both *sativa* and *sterilis* articulations." The description of the mass color of this strain in 1920 was "pale buckthorn brown."

Kansas No. 5211 (C. I. No. 1917) was received from Prof. T. A. Kiesselbach, of the Nebraska Agricultural Experiment Station, in 1918. This strain was described in 1919 as having "weak awns, smooth and pubescent grains, light red to brown in color and both the *sterilis* and *sativa* types of articulation." The mass color description for this strain was "light buckthorn brown."

Kansas No. 5219 (C. I. No. 2023) was received from Albert Goenner, a farmer of Zenda, Kingman County, Kans., in March, 1920. The selections were made from the original sample of seed as obtained from Mr. Goenner. The mass color description of this variety was "primuline yellow."

Kansas No. 5220 (C. I. No. 293) was received from the Belle Fourche Experiment Farm of the Office of Western Irrigation Agriculture, Bureau of Plant Industry, United States Department of Agriculture, at Newell, S. Dak., in 1916. Although this strain carries the same Cereal Investigations number (293) as Kansas No. 5020, it may have a different origin and history. Burt, C. I. No. 293, is known to vary widely in general appearance at the different stations at which it is being grown. The 1919 description of Kansas No. 5220, as grown at the Kansas station, was "weak awns, smooth and pubescent grains, light yellow to brown in color, with the *sterilis* and *sativa* types of articulation." This strain of Burt oats had a higher proportion of dark-colored florets than any other strain used in these experiments. The description of mass color is "dark buckthorn brown."

Kansas No. 6004 (C. I. No. 1918) originated as a selection from Burt, Kansas No. 5020. The selection was made at the Kansas Agricultural Experiment Station in 1910. The 1919 description for this strain was "awnless, smooth grains, yellow to dark red in color, and *sativa* and *sterilis* articulation." The description of mass color for the strain was "cream color."

Kansas No. 6052 (C. I. No. 1919) also is a selection from Kansas No. 5020, made at the Kansas station in 1911. In 1919 the strain was described as "awnless, smooth grained, light yellow to dark red in color, having both *sterilis* and *sativa* types of articulation." About 98 per cent of the kernels were of a light color. The mass color of this strain was "buff yellow."

Kansas No. 6076 (C. I. No. 1920) originated as a selection from Burt, Kansas No. 5020. This selection was made at the Kansas Agricultural Experiment Station in 1912. The 1919 description for this selection was "awnless, smooth grains, light yellow to brown in color and both the *sativa* and *sterilis* types of articulation." About 75 per cent of the kernels were yellow in color. The description of the mass color for this strain was "maize yellow."

Kansas No. 6090 (C. I. No. 1921) was received in 1918 from Prof. L. C. Burnett, of the Iowa Agricultural Experiment Station. The Iowa nursery row number was 1711, and the seed was described as having "dark kernels." The description of the strain as grown at the Kansas station in 1919 was "awnless, smooth grained, light red to dark brown in color with about 75 per cent of dark kernels, and both the

[21] In this and the following descriptions the word "smooth" means glabrous or without pubescence; the word "grains" means the florets or more particularly the lemmas; and the word "articulation" means disjunction either by disarticulation or by fracture of the rachilla segment. The name "*sterilis*" refers to the cultivated derivatives of that species which in this paper are grouped under the specific name *byzantina*. The color descriptions were made by Mr. S. Fred Prince, biological artist at the Kansas Agricultural Experiment Station. The terms used are those given by Ridgway (*10*) for the corresponding colors.

EXPLANATORY LEGEND FOR PLATE 4

Lemma colors of three strains of Burt oat in 1919. A to E.—Kansas No. 6090: A, black; B, dark brown; C, red; D, reddish yellow; E, red. F to K.—Kansas No. 5219: F, dark brown; G, light brown; H, red; I, yellowish-white; J, gray; K, white. L to Q.—Kansas No. 5220: L, dark brown; M, light brown; N, red; O, yellow; P, white; Q, red.

sativa and *sterilis* types of articulation." The description of mass color for this strain was "mummy brown."

Kansas No. 6094 (C. I. No. 1923) also was received from Prof. L. C. Burnett, of the Iowa Agricultural Experiment Station. Professor Burnett has given the following history and description for this strain: "A pure-line selection made from Burt by Norton before 1906, at the Funk Brothers' Farm, Bloomington, Ill. For many years this was the only variety of Burt at Ames and still is a very good line." The following description was given this strain as grown at the Kansas station in 1919: "Awned, smooth and pubescent grains, light yellow to brown in color and with both *sativa* and *sterilis* types of articulation." The mass color of the florets of this strain was described as "pale buckthorn brown."

EXPERIMENTAL METHODS

The previous observations of the writers had shown marked variability in the Burt oat and arrangements were made for studying the problem cooperatively. Experiments were started at the Akron Field Station and at the Kansas Agricultural Experiment Station in the spring of 1920. In order to coordinate the experiments at the two stations experiments with the Akron selections were discontinued and only the Kansas strains described above were used.

METHODS IN 1920

Kernels were selected individually from each of the nine different lots of bulk seed described under "Experimental material." The attempt was made to select from each of the nine strains about 25 kernels representing each of the recognized phases of the five characters studied. These characters and the number of different phases originally recognized were as follows: Spikelet disarticulation, 3 phases; floret disjunction, 2 phases; basal hairs, 3 phases; awns, 3 phases; lemma color, 6 phases. It was not possible to find so many as 25 primary kernels representing some phases of some characters, while more than 25 were readily obtained in other cases. Only primary or lower kernels to the spikelets were chosen for study. Somewhere between 2,000 and 2,500 kernels were individually selected. About one-third of this material was retained for sowing at the Kansas station and the other two-thirds taken to Akron for sowing there.

At Akron, Colo., those kernels from each strain which represented one phase of each of the five characters were grouped together and grown as a single class. Each plant in each class was numbered at maturity and handled individually thereafter. At the Kansas station each kernel was described individually and given a pedigree number before sowing. With this exception the method of procedure at the two stations differed in minor details only.

There was a slight difference in the manner of describing the original kernels at the two stations. At Akron the nature of the awns was described for each kernel, while at Manhattan only the presence or absence of awns was noted. At Akron only a few of the original lower kernels were classified as having an intermediate type of spikelet disarticulation, while at Manhattan they were separated rather equally into the three groups based on the manner of disarticulation. At Akron a color class, containing variegated kernels, was recognized in 1920, while no such class was recognized at Manhattan.

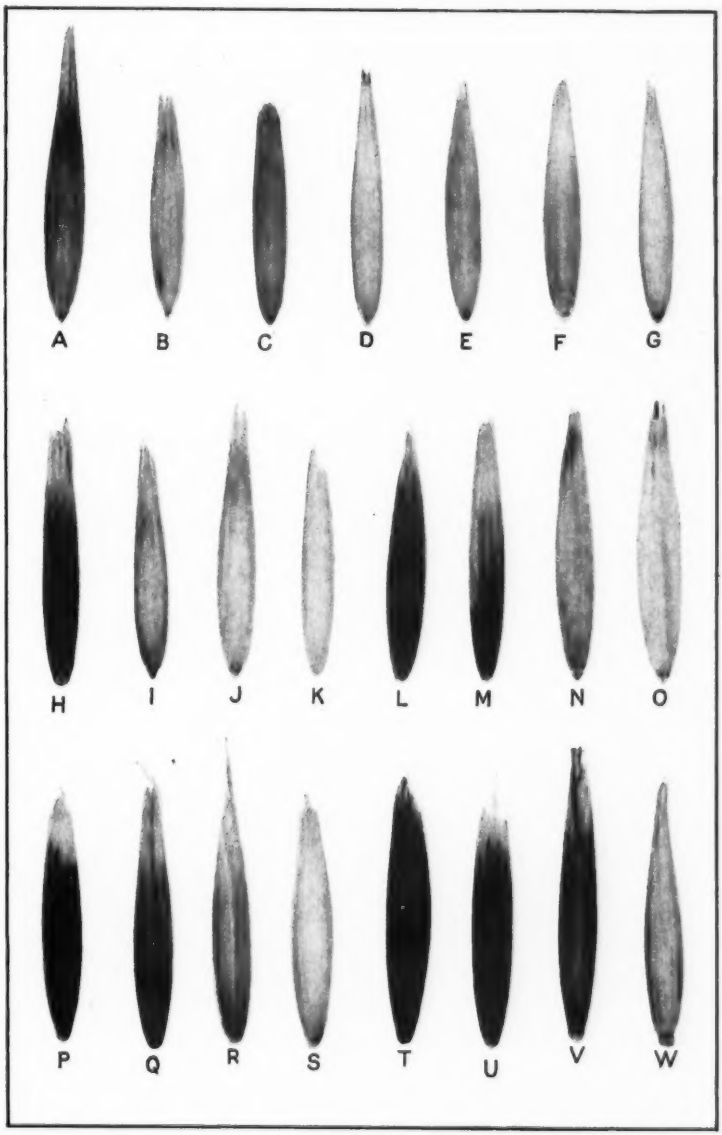
With one exception, seedlings of all strains were made at the Akron Field Station and the Kansas Agricultural Experiment Station in 1920. No seedings of kernels from the Kansas strain No. 5219 were made at Akron. The methods of seeding at the two stations were very similar. Sowing at Akron was done on April 29 and 30 inside a screened shelter, in 10-inch rows with the plants 4 inches apart in the rows. At Manhattan, Kans., sowings were made on April 15, the late spring having made sowing at the normal time impossible. At that station the kernels were spaced 6 inches apart in 12-inch rows.

Before harvest the plants grown at Akron were numbered individually and notes were taken on the number and height of culms, number of panicles, length of main panicle, and date of heading. At Manhattan notes on date of heading and ripening were recorded.

At Akron at harvest time the plants representing each of the score or more

EXPLANATORY LEGEND FOR PLATE 5

Lemma colors of six strains of Burt oat in 1919. A to D.—Kansas No. 6004: A, light red; B, yellow; C, light red; D, white. E to G.—Kansas No. 6052: E, light red; F, yellow; G, white. H to K.—Kansas No. 6076: H, dark brown; I, red; J, yellow; K, white. L to O.—Kansas No. 5020: L, dark brown; M, light brown; N, reddish yellow; O, white. P to S.—Kansas No. 5211: P, black; Q, dark brown; R, red; S, white. T to W.—Kansas No. 6094: T, black; U, dark brown; V, grayish red; W, yellowish white.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of character phases in each of the eight strains were pulled and tied together in a bundle. When cured the heads were removed, labeled with the strain number, the class or character phase, and the individual plant number, and shipped to Manhattan for study.

The general plan was to describe at least 25 primary kernels from each plant grown in 1920. Usually all of the primary kernels on the main panicle were described; but where the main panicle did not provide 25 kernels the additional number required was taken from a secondary panicle. The secondary kernels of the spikelets were not described as such in this study but only the method of their disjunction. The kernels were taken from the panicle in a definite order from the base to the top. It was thought that some definite and progressive variation might exist within the panicle, but the results obtained do not indicate such an arrangement. The same characters described in the parental material were used in the descriptions of the progeny kernels of the 1920 crop, namely, (1) spikelet disarticulation; (2) floret disjunction; (3) basal hairs; (4) awns; and (5) lemma color.

Special forms were devised for recording descriptions of the kernels, check marks being made under the proper headings. There were slight differences in the descriptions of the kernels grown at the two stations because the Manhattan material was described first and as the work progressed several minor changes were made.

At first no distinction was made between the abundant long and the abundant midlength subclasses of basal hairs. This distinction was first made toward the end of the study of the 1920 Manhattan material and was continued throughout the description of the Akron material. Shortly after the descriptions of the Akron material was started it appeared advisable to divide the brown color class into dark brown and light brown. No intermediate subclass in floret disjunction was recognized in describing the original kernels, but it was used when describing the kernels of plants grown in 1920.

The percentage of kernels described as being intermediate (heterofracture) for floret disjunction was much higher in the 1920 crop from Akron than in the 1920 crop grown at Manhattan. This may be partly owing to differences in individual judgment, the Manhattan and the Akron material in 1920 being described by two different persons.

METHODS IN 1921

In planning the 1921 experiments it was decided to grow all of the classes and subclasses of kernels representing distinct individual characters and as many different combinations of these as possible. The kernels from each plant grown in 1920 were carefully examined and as complete an array as possible of these characters and combinations of characters was chosen from each of the nine parental strains for sowing in 1921. In making these selections never less than 5 nor more than 10 kernels of a single subclass from any one plant were sown. For example, if in studying floret disjunction in the 25 kernels from plant No. 5211–5–10 (Kansas strain No. 5211, group 5, plant No. 10) 15 kernels were designated by disarticulation and the other 10 kernels by basifracture, probably 10 kernels of each of these two types of floret disjunction were selected for growing. Those of one disjunction type would be grown in 1921 as No. 5211–5–10–1 and those of the other type as 5211–5–10–2. All of the kernels representing a given class or subclass sown in the 1921 experiments at Akron came from the same parent plant. As a rule but few plants derived from any one original strain and bearing the same classification were used for seed, as otherwise the material would soon have become too extensive.

The same general plan was followed in making the kernel selections from the 1920 plants grown at Manhattan, although some classes were chosen for studying the inheritance of a particular character, or combination of characters, without describing all of the other characters of the kernels.

Approximately 800 kernels were selected and sown in the 1921 experiments at Akron. The weather was very dry and grasshoppers did considerable damage to the plants.

Between 500 and 600 kernels were selected, described, and sown in the 1921 experiments at Manhattan. Weather conditions were favorable and the crop made a normal growth. However, a serious infestation of chinch bugs occurred in late June and early July and greatly checked the growth of the plants, with the result that a considerable percentage of the kernels failed to reach their full development.

The general procedure in conducting the 1921 experiments was the same at the two stations. The same notes on plant characters were taken as in 1920.

The plants grown at Akron in 1921 were packed in boxes and mailed to Manhattan, where the material from both stations was described.

EXPERIMENTAL RESULTS

About 60,000 kernels were examined in the course of this study, but space will not permit the inclusion of more than the summary tables of the results obtained. The data will be discussed for each character separately. The five characters are spikelet disarticulation, floret disjunction, basal hairs, awns, and lemma color, as described under experimental methods.

SPIKELET DISARTICULATION

The disarticulation of the spikelet from the lower segment of the rachilla is one of the fundamental characters in classifying oats. In this study disarticulation was described as resulting from "abscission," "semiabscission," or "fracture." Kernels having a clean, sharp separation with a prominent basal cavity with calloused margins, as found in Red Rustproof and other typical varieties of *Avena byzantina*, were described as disarticulating by abscission. This type of separation is illustrated in Plate 1, A. Those kernels having the characteristic roughish fracture and pointed base shown in Plate 1, C without smooth scar tissue or cavity, and generally associated with *Avena sativa* varieties such as Swedish Select were described as disarticulating by fracture. Kernels having a poorly or only partially developed basal cavity with rough tissue surrounding it were described as resulting from semiabscission. A kernel having this basal form is shown in Plate 1, B. The results from the studies of 1920 and 1921 are presented separately.

In selecting the original kernels from the bulk material preparatory to starting these experiments, only the two types, abscission and fracture, were chosen in any considerable number from any of the strains. A few kernels disarticulating by semiabscission, however, were sown at each station. At the Akron station so few kernels of the semiabscission class were selected in any of the strains, with the exception of Kansas No. 5211, that these few kernels were not classified separately but were included with those in which spikelet disarticulation was by abscission.

RESULTS IN 1920

The detailed and summarized results of the study of spikelet disarticulation in 1920 are given in Table I.

The data presented in Table I indicate significant differences among the strains. In only six strains at Manhattan and in seven out of eight at Akron were parental kernels found which disarticulated by abscission. This clearly indicates that variation exists among different Burt oat strains with respect to this character.

Kernels in which spikelet disarticulation resulted from abscission tend to produce progeny of the same type. Parental kernels described as disarticulating by fracture produced progeny of which about three-fourths disarticulated by fracture. Kernels in which spikelet disarticulation was classed as resulting from semiabscission were found in appreciable percentages in the progenies of all three parental classes.

Kernels having the prominent basal cavity associated with abscission were found in the progeny of fracturing parental kernels, which have no cavity, in six strains at each station. Two strains, Kansas Nos. 5219 and 5220, at Manhattan, and one strain, Kansas No. 6004, at Akron, produced no kernels in which spikelet disarticulation was described as by fracture in the progenies of parental kernels disarticulating by abscission and semiabscission combined.

The disarticulation resulting from fracture was very definitely inherited. At both stations, in all strains, with the exception of Kansas No. 6090 grown at Akron, the parental kernels in which the spikelet disarticulation was described as fracture produced progeny of which 60 per cent or more was described as disarticulating by fracture. In general the results obtained show a rather strong correlation between parent and progeny in spikelet disarticulation.

From the data in Table I it is evident that spikelet disarticulation is inherited in a definite manner. The summarized data indicate that there was a strong tendency for the kernels disarticulating by abscission and by fracture to transmit these characters to their progeny. The kernels in the class disarticulating by semiabscission tended to produce progeny almost equally divided among the three spikelet disarticulation types.

RESULTS IN 1921

Table II presents the data obtained at Akron in 1921 on the inheritance of spikelet disarticulation. (Since the plants of Burt oats at Manhattan did not attain full development because of the ravages of chinch bugs, accurate classification with regard to spikelet

TABLE I.—*Data on inheritance of three different methods of spikelet disarticulation in the progeny of selected kernels of each of nine strains of the Burt oat when grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1920*

Strain number and method of disarticulation in parent kernels	Kernels in progeny					
	Number disarticulating by—			Percentage disarticulating by—		
	Abscission	Semiabscission	Fracture	Abscission	Semiabscission	Fracture
AKRON FIELD STATION						
Kansas No. 5020:						
Abscission	419	506	71	42.1	50.8	7.1
Semiabscission						
Fracture	26	734	1,205	1.3	37.4	61.3
Kansas No. 5211:						
Abscission	3,439	543	276	80.8	12.7	6.5
Semiabscission	291	75	2	79.1	20.4	.5
Fracture	637	1,176	3,298	12.5	23.0	64.5
Kansas No. 5220:						
Abscission	91	109	20	41.4	49.5	9.1
Semiabscission						
Fracture	10	404	1,000	.7	28.6	70.7
Kansas No. 6004:						
Abscission	77	96	0	44.5	55.5	0
Semiabscission						
Fracture	24	54	913	2.4	5.5	92.1
Kansas No. 6052:						
Fracture	0	118	3,242	0	3.5	96.5
Kansas No. 6076:						
Abscission	60	194	113	16.3	52.9	30.8
Semiabscission						
Fracture	0	213	1,471	0	12.6	87.4
Kansas No. 6090:						
Abscission	702	650	118	47.8	44.2	8.0
Semiabscission						
Fracture	418	667	1,013	19.9	31.8	48.3
Kansas No. 6094:						
Abscission	621	133	76	74.8	16.0	9.2
Semiabscission						
Fracture	109	301	1,333	6.2	17.3	76.5
All 8 strains:						
Abscission	5,409	2,231	674	65.1	26.8	8.1
Semiabscission	291	75	2	79.1	20.4	.5
Fracture	1,224	3,667	13,475	6.6	20.0	73.4
KANSAS AGRICULTURAL EXPERIMENT STATION						
Kansas No. 5020:						
Abscission	145	144	45	43.4	43.1	13.5
Semiabscission	29	74	257	8.0	20.6	71.4
Fracture	35	178	736	3.7	18.8	77.5
Kansas No. 5211:						
Abscission	528	148	65	71.2	20.0	8.8
Semiabscission	148	142	139	34.5	33.1	32.4
Fracture	123	142	624	13.8	16.0	70.2
Kansas No. 5219:						
Abscission	456	275	0	62.4	37.6	0
Semiabscission	237	340	61	37.1	53.3	9.6
Fracture	44	153	338	8.2	28.6	63.2
Kansas No. 5220:						
Abscission	89	7	0	89.4	10.6	0
Semiabscission	16	39	130	8.6	21.1	70.3
Fracture	26	123	479	4.1	19.6	76.3
Kansas No. 6004:						
Semiabscission	0	17	25	0	40.5	59.5
Fracture	0	1	894	0	.1	99.9
Kansas No. 6052:						
Semiabscission	0	17	2	0	89.5	10.5
Fracture	0	4	1,398	0	.3	99.7
Kansas No. 6076:						
Semiabscission	0	2	6	0	25.0	75.0
Fracture	0	88	899	0	8.9	91.1
Kansas No. 6090:						
Abscission	232	182	17	53.8	42.2	4.0
Semiabscission	57	145	111	18.2	46.3	35.5
Fracture	58	80	479	9.4	13.0	77.6

TABLE I.—*Data on inheritance of three different methods of spikelet disarticulation in the progeny of selected kernels of each of nine strains of the Burt oat when grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1920*—Continued

Strain number and method of disarticulation in parent kernels	Kernels in progeny					
	Number disarticulating by—			Percentage disarticulating by—		
	Abscission	Semiabscission	Fracture	Abscission	Semiabscission	Fracture
KANSAS AGRICULTURAL EXPERIMENT STATION—continued						
Kansas No. 6004:						
Abscission	150	3	13	90.4	1.8	7.8
Semiabscission	25	63	73	15.5	39.1	45.4
Fracture	3	205	348	.5	36.9	62.6
All 9 strains:						
Abscission	1,570	759	140	63.6	30.7	5.7
Semiabscission	512	839	804	23.8	38.9	37.3
Fracture	289	974	6,195	3.9	13.0	83.1
BOTH STATIONS						
Abscission	6,979	2,990	814	64.7	27.7	7.6
Semiabscission	803	914	806	31.8	36.2	32.0
Fracture	1,513	4,641	19,670	5.8	18.0	76.2

disarticulation was impossible and no data on this character are included.) The abscission type bred true in 92.4 per cent of the kernels grown from parental kernels described as disarticulating by this method.

The parental kernels in which spikelet disarticulation was classed as resulting from semiabscission, produced progeny containing approximately three individuals in which spikelet disarticulation occurred by semiabscission or fracture to one by abscission. The parental kernels in which spikelet disarticulation was described as fracture, produced progeny of which the spikelet disarticulation was 64.3 per cent by fracture, 33.2 per cent by semiabscission, and 2.5 per cent by abscission.

It would appear from the 1921 data on the inheritance of spikelet disarticulation that in the Burt oat the spikelet disarticulation by fracture is dominant and that by abscission recessive. The class here described as resulting by semiabscission possibly represents the heterozygous group. These results seem to be in general agreement with those of Surface (*127*), Love and Craig (*70*), and Fraser (*37*), who studied the inheritance of the basal scar as an expression of this character.

The results obtained agree with those of previous investigators and indicate that spikelet disarticulation behaves as a simple monohybrid. Fracture or the absence of basal cavity probably is dominant, or at least partially so, over abscission or presence of a basal cavity which seems to behave as a recessive.

Etheridge (*33*) believed that the basal cavity is of little use in classifying oat varieties. The results of many investigators indicate that this character is of distinct value in classifying oats and that it is more or less constant in its breeding behavior. This character has been much used in distinguishing oat varieties of the *Avena byzantina* group from those of the *sativa* group and it is thought to be of more value than the statement of Etheridge would indicate.

FLORET DISJUNCTION

The floret disjunction classes previously described are disarticulation (as in *A. sativa*), heterofracture, and basifracture (as in *A. byzantina*). These three ways by which floret disjunction takes place are illustrated in Plate 1, D to F, inclusive. The term heterofracture was used for the method of disjunction of those florets or kernels in which the rachilla segment broke variously at or near the midpoint, as shown in Plate 1, E. In these cases part of the rachilla remained with the primary kernel of the spikelet and part of it broke off with the secondary kernel.

TABLE II.—*Data on inheritance of three different methods of spikelet disarticulation in the progeny of selected kernels of each of eight strains of the Burt oat when grown at the Akron Field Station in 1921*

Strain number and method of disarticulation in parent kernels	Kernels in progeny					
	Number disarticulating by—			Percentage disarticulating by—		
	Abscission	Semiabscission	Fracture	Abscission	Semiabscission	Fracture
Kansas No. 5020:						
Semiabscission	266	449	34	35.5	60.0	4.5
Fracture	0	108	.195	0	35.6	64.4
Kansas No. 5211:						
Abscission	1,135	111	2	90.9	8.9	.2
Semiabscission	41	418	108	7.2	73.7	19.1
Fracture	73	337	926	5.5	25.2	69.3
Kansas No 5220:						
Abscission	91	0	0	100.0	0	0
Semiabscission	1	144	6	.6	95.4	4.0
Fracture	0	144	180	0	44.4	55.6
Kansas No. 6004:						
Fracture	0	0	29	0	0	100.0
Kansas No. 6052:						
Semiabscission	0	73	4	0	94.8	5.2
Fracture	0	114	147	0	43.7	56.3
Kansas No. 6076:						
Abscission	0	0	6	0	0	100.0
Semiabscission	53	158	44	20.8	61.9	17.3
Fracture	0	14	262	0	5.1	94.9
Kansas No. 6090:						
Abscission	345	20	0	94.5	5.5	0
Semiabscission	63	117	8	33.5	62.2	4.3
Fracture	0	112	71	0	61.2	38.8
Kansas No 6094:						
Abscission	130	1	0	99.2	0.8	0
Semiabscission	109	21	9	78.4	15.1	6.5
Fracture	0	151	87	0	63.4	36.6
All strains:						
Abscission	1,701	132	8	92.4	7.2	.4
Semiabscission	533	1,380	213	25.1	64.9	10.0
Fracture	73	980	1,897	2.5	33.2	64.3

STUDY IN 1920

Table III presents the data on floret disjunction for each strain grown at Akron and Manhattan in 1920. The numbers of kernels studied and percentages falling into each disjunction class are given. The combined data for all strains at each station and at both stations are shown also. The parental kernels sown in 1920 were separated into only two classes for disjunction. The kernels properly representing the intermediate class (heterofracture) probably went mostly into the basifracture class.

A study of the data on floret disjunction in the 1920 crop indicates that the *sativa* type (which disarticulates) is much more stable in breeding behavior than the *sterilis* type (which separates by basifracture). More than 67 per cent of the progeny kernels produced at both Akron and Manhattan from parental kernels disjoining by disarticulation were described as disarticulating, slightly less than 23 per cent as separating by heterofracture, and only 10 per cent as separating by basifracture.

Only 18.3 per cent of progeny kernels in which disjunction took place by basifracture were produced from parental kernels so classed. More than twice as many of the 1920 progeny from kernels of this class, or 47.1 per cent, were described as disjoining by disarticulation as by basifracture, while in 34.6 per cent disjunction was described as by heterofracture.

Comparatively few of the kernels in which floret disjunction was classed as taking place by basifracture bred true in 1920. These data indicate that in this material the disarticulation form is more stable in breeding behavior than the basifracture form of disjunction.

The summarized data for each of the two stations show that the percentage of progeny kernels disjoining by disarticulation, and produced from parental kernels so classed, was about 66 per cent at Akron and 73 per cent at Manhattan. The percentage of progeny kernels disjoining by heterofracture and grown from parent kernels in which disjunction was classed as by disarticulation and as by basifracture varied considerably at the

two stations. This probably was partly owing to the fact that the descriptions of the kernels grown at the two stations in 1920 were made by different persons. The percentage of basifracture kernels in the progeny of parental kernels described as disjoining by disarticulation was much lower at Akron, 8 per cent, than at Manhattan, 21.7 per cent.

In the progeny of parental kernels in which disjunction was described as by basifracture, 13.5 per cent of the kernels grown at Akron and 31.8 per cent of the kernels grown at Manhattan were so described. In the progenies of parental kernels in which disjunction was described as by basifracture there were about 61 per cent by disarticulation in the Manhattan material and about 42 per cent in the Akron material.

The highest percentage of progeny kernels of which floret disjunction was described as by basifracture, produced from parental kernels so classed, was found in strain Kansas No. 5211 at Akron and in strain No. 5219 at Manhattan. Kansas No. 5219 was not grown at Akron. The percentage of disjunction by disarticultion in the progeny of parental kernels in which disjunction was described as by basifracture was not far below 60 per cent in any of the strains at either station, with the exception of Kansas No. 6090, grown at Akron, and Kansas No. 5219, grown at Manhattan. In Kansas No. 6052, grown at Akron, and Kansas Nos. 6052 and 6076, grown at Manhattan, less than 5 per cent of the progeny kernels of parental kernels in which floret disjunction was described as by basifracture were so classed. In each of these three cases, in about 90 per cent or more of the progeny of the basifracture parental type, disjunction was described as by disarticulation. The comparatively small number of individuals of each of these strains, however, makes it unwise to consider these results conclusive.

An examination of the data for each of the strains at both stations indicates that of the disjunction types the lowest percentages of progeny described as disarticulating, from parental kernels so described, were produced in those strains which had the highest percentages of progeny disjunction by basifracture produced from parents of that type. In most of the strains grown at each station approximately two-thirds, and in many cases three-fourths or more, of the progeny from parental kernels disjoining by disarticulation were described as disarticulating.

The results of the 1920 studies on floret disjunction clearly indicate that the form resulting from basifracture in all of the strains under observation was much less stable in breeding behavior than was the form resulting from disarticulation. A comparatively small percentage of the parental kernels in which disjunction took place by basifracture produced progeny so described, while in most strains at both stations two-thirds or more of the progeny kernels from parental kernels in which disjunction was described as by disarticulation were of this type.

STUDY IN 1921

Floret disjunction in the progeny kernels grown in 1921 at Akron was described in the same way as in 1920. (Chinch bugs damaged the oat plants at Manhattan to such an extent that it is impossible to include data for the 1921 crop at that place.) The results obtained in 1921, presented in Table IV, are in general agreement with those obtained in 1920.

An examination of the data shows that a comparatively small percentage of the kernels in which disjunction was classed as by basifracture bred true. In each of the five strains where progenies were produced from kernels so described less than 20 per cent of the progeny kernels in any strain disjoined by basifracture. This indicates that in the Burt oat used in these experiments disjunction by basifracture is very unstable in its breeding behavior, producing larger percentages of progeny in which disjunction takes place by disarticulation and by heterofracture than by basifracture even in the second year of pedigree culture.

The kernels in which disjunction was described as by heterofracture in 1920 produced progenies in 1921 of which approximately 45 per cent of the kernels disjoined by heterofracture, 44 per cent by disarticulation, and 11 per cent by basifracture. It is possible that in describing the 1920 material a larger number of kernels of which disjunction was genetically by disarticulation than of those in which it was genetically by basifracture was classed as by heterofracture.

The results obtained in the progenies from kernels of which disjunction was classed as by disarticulation in 1920 indicate that disarticulation is comparatively stable in breeding behavior. The progeny kernels produced in 1921 from the kernels of which disjunction was by disarticulation showed about 74 per cent disjoining by disarticulation, 22 per cent by heterofracture, and less than 5 per cent by basifracture.

TABLE III.—*Data on inheritance of three different methods of floret disjunction in the progeny of selected kernels of each of nine strains of the Burt oat when grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1920*

Strain number and method of disjunction in parent kernels[a]	Kernels in progeny					
	Number disjoining by—			Percentage disjoining by—		
	Basi-fracture	Hetero-fracture	Disarticulation	Basi-fracture	Hetero-fracture	Disarticulation
AKRON FIELD STATION						
Kansas No. 5020:						
Basifracture	32	207	293	6.0	38.9	55.1
Disarticulation	76	568	1,785	3.1	23.4	73.5
Kansas No. 5211:						
Basifracture	503	1,535	814	17.6	53.8	28.6
Disarticulation	804	2,447	3,156	12.5	38.2	49.3
Kansas No. 5220:						
Disarticulation	175	413	1,046	10.7	25.3	64.0
Kansas No. 6004:						
Basifracture	9	17	52	11.5	21.8	66.7
Disarticulation	19	119	948	1.7	11.0	87.3
Kansas No. 6052:						
Basifracture	8	27	302	2.4	8.0	89.6
Disarticulation	121	273	2,629	4.0	9.0	87.0
Kansas No. 6076:						
Basifracture	88	93	404	15.0	15.9	69.1
Disarticulation	104	172	1,190	7.1	11.7	81.2
Kansas No. 6090:						
Basifracture	143	684	358	12.1	57.7	30.2
Disarticulation	212	742	1,429	8.9	31.1	60.0
Kansas No. 6094:						
Basifracture	76	257	477	9.4	31.7	58.9
Disarticulation	107	498	1,158	6.1	28.2	65.7
All strains:						
Basifracture	859	2,818	2,700	13.5	44.2	42.3
Disarticulation	1,618	5,232	13,341	8.0	25.9	66.1
KANSAS AGRICULTURAL EXPERIMENT STATION						
Kansas No. 5020:						
Basifracture	65	12	172	26.1	4.8	69.1
Disarticulation	24	6	111	17.0	4.3	78.7
Kansas No. 5211:						
Basifracture	152	29	269	33.8	6.4	59.8
Disarticulation	254	78	574	28.0	8.6	63.4
Kansas No. 5219:						
Basifracture	381	101	425	42.0	11.1	46.9
Disarticulation	244	49	452	32.7	6.6	60.7
Kansas No. 6004:						
Basifracture	13	8	91	11.6	7.1	81.3
Disarticulation	1	1	89	1.1	1.1	97.8
Kansas No. 6052:						
Basifracture	6	4	125	4.4	3.0	92.6
Disarticulation	14	7	328	4.0	2.0	94.0
Kansas No. 6076:						
Basifracture	1	1	80	1.2	1.2	97.6
Disarticulation	13	1	127	9.2	0.7	90.1
Kansas No. 6090:						
Basifracture	79	12	130	35.8	5.4	58.8
Disarticulation	109	31	447	18.6	5.3	76.1
Kansas No. 6094:						
Basifracture	26	6	87	21.9	5.0	73.1
Disarticulation	102	9	434	18.7	1.7	79.6
All strains:						
Basifracture	723	173	1,379	31.8	7.6	60.6
Disarticulation	761	182	2,562	21.7	5.2	73.1
BOTH STATIONS						
Basifracture	1,582	2,991	4,079	18.3	34.6	47.1
Disarticulation	2,379	5,414	15,903	10.0	22.9	67.1

[a] None of the parental kernels sown in 1920 was described as having intermediate or heterofracture disjunction.

TABLE IV.—*Data on inheritance of three different methods of floret disjunction in the progeny of selected kernels of each of eight strains of the Burt oat when grown at the Akron Field Station in 1921*

Strain number and method of disjunction in parent kernels	Kernels in progeny					
	Number disjoining by—			Percentage disjoining by—		
	Basifracture	Heterofracture	Disarticulation	Basifracture	Heterofracture	Disarticulation
Kansas No. 5020:						
Basifracture	3	7	21	9.7	22.6	67.7
Heterofracture	10	96	84	5.3	50.5	44.2
Disarticulation	33	169	629	4.0	20.3	75.7
Kansas No. 5211:						
Basifracture	84	162	181	19.7	37.9	42.4
Heterofracture	151	408	442	15.1	40.7	44.2
Disarticulation	92	469	1,162	5.3	27.2	67.5
Kansas No. 5220:						
Basifracture	2	9	34	4.4	20.0	75.6
Heterofracture	6	28	70	5.8	26.9	67.3
Disarticulation	15	40	362	3.6	9.6	86.8
Kansas No. 6004:						
Disarticulation	1	2	26	3.4	6.9	89.7
Kansas No. 6052:						
Heterofracture	0	0	7	0	0	100.0
Disarticulation	6	28	279	1.8	8.5	89.7
Kansas No. 6076:						
Basifracture	5	28	16	10.2	57.1	32.7
Heterofracture	0	20	5	0	80.0	20.0
Disarticulation	30	124	309	6.5	26.8	66.7
Kansas No. 6090:						
Heterofracture	43	300	221	7.6	53.2	39.2
Disarticulation	4	26	142	2.3	15.1	82.6
Kansas No. 6094:						
Basifracture	2	34	49	2.4	40.0	57.6
Heterofracture	8	64	57	6.2	49.6	44.2
Disarticulation	9	79	206	3.1	26.9	70.0
All strains:						
Basifracture	96	240	301	15.1	37.7	47.2
Heterofracture	218	916	886	10.8	45.3	43.9
Disarticulation	190	937	3,133	4.5	22.0	73.5

The results of the 1921 experiments on the inheritance of floret disjunction indicate the correctness of the conclusions drawn in 1920 and confirm the statement that floret disjunction by basifracture as observed in these Burt oat strains is very much less stable in breeding behavior than is that by disarticulation.

A review of the data on floret disjunction obtained in these experiments indicates that the disjunction resulting from disarticulation is the more stable in breeding behavior. The results for the two years were similar in this respect. The results obtained by Fraser (*37*), in his cross of Burt (*sterilis* type) × Sixty-Day (*sativa* type) indicated that the *sativa* type of floret disjunction by disarticulation is dominant over the *sterilis* type which results from basifracture and that a single factor difference governs the inheritance of floret disjunction.

The data presented on the inheritance of the floret disjunction in the Burt oat indicates that, to explain the breeding behavior of this character in this variety on a factorial basis, it will be necessary to conduct carefully controlled hybridization experiments using parental material of which the breeding behavior for this character is definitely known.

BASAL HAIRS

In classifying the material from the nine strains of Burt oat used, three quantity classes for basal hairs were recognized, namely, abundant, few, and absent. In describing the progeny kernels of the 1920 crop a subdivision of the first class seemed necessary to allow separation of long and mid-length hairs. As the kernels grown in 1919 and sown in the 1920 experiments were machine threshed, many of the basal hairs were rubbed off and for that reason classification of the original material was subject to error. In some cases kernels which had borne hairs probably lost all or many of them in threshing and an erroneous description resulted.

Kernels described in 1920 as subclass abundant long had a dense growth of long basal hairs which sometimes almost surrounded the base of the lemma (Pl. 2, A). The basal hairs described as abundant midlength (Pl. 2, B) were not so long as those in the abundant long subclass and often they were not produced so abundantly. Kernels described as having few basal hairs usually had only a few short hairs around the base of the kernel (Pl. 2, C), although some kernels bearing a very few long hairs were included. Kernels which bore long hairs usually had them abundantly developed. Kernels bearing no visible hairs were classed as absent (Pl. 1, B, C, E).

STUDY IN 1920

The data on basal hairs from both stations in 1920, presented in Table V, clearly indicate that all of the three parental types segregated to a considerable degree. The abundant class was a little more constant in breeding behavior than either of the others. The class termed few was the least constant. In general, however, each parental class produced progenies having a slightly larger number of kernels of its own class than of either of the other classes.

An examination of the data for each strain shows that in only five of the eight strains grown at Akron were any of the parental kernels described as having abundant hairs. If the percentages of kernels classed as abundant midlength and abundant long produced from the parental kernels in the abundant class are added together for all strains grown at Akron, nearly 85 per cent of the progeny kernels are in the two abundant subclasses. The percentages range from 75 per cent in Kansas No. 6076 to 93.5 per cent in Kansas No. 6090. In all strains grown at Akron in 1920 the parental kernels described as having abundant basal hairs produced progenies in which practically no kernels were classed as having basal hairs absent, although 9.2 per cent of such kernels occurred in Kansas No. 5211. In Kansas No. 5020 only two kernels and in Kansas No. 6076 only one kernel having no basal hairs occurred in progenies of parental kernels having abundant hairs. As a rule the parental kernels classed as having abundant basal hairs were more nearly constant in breeding behavior than either of the other two classes. These data show clearly how few kernels genetically having long hairs were classed as having few hairs.

In many of the strains the kernels classed as having few basal hairs produced a majority of kernels of the abundant hair class. Of all of the strains at both stations parental kernels with few hairs produced only 2.5 per cent of progeny kernels with hairs classed as abundant long and only 5.1 per cent classed as absent, while 44.9 per cent were classed as abundant midlength, and 47.5 per cent as few. The parental kernels classed as having no basal hairs produced 6.8 per cent with hairs described as abundant midlength, and only 0.3 per cent with abundant long hairs, but 36.4 per cent with few, and 56.5 per cent with hairs absent. Of all of the eight strains only 36.4 per cent of the progeny of parental kernels having absent basal hairs were classed as having few hairs.

The summary shows that all parental classes produced some kernels in all of the classes of basal hairs. Those parental kernels classed as having abundant hairs bred true in 76 per cent of the cases, if the abundant long and midlength subclasses are considered together. Parental kernels classed as having few hairs produced progenies consisting very largely of the abundant midlength and few classes. The parental kernels classed as having hairs absent produced progeny of which only 56.5 per cent were so described, while 43.5 per cent bore basal hairs.

STUDY IN 1921

The 1921 data on inheritance of basal hairs are presented in Table VI. No kernels described as having abundant long basal hairs were sown at Manhattan. At Akron these kernels produced progeny of which 95 per cent were like the parents and 5 per cent had abundant midlength hairs. This would indicate that the abundant long class of basal hairs breeds as a recessive. Kernels described as having abundant midlength basal hairs produced progenies of which 53.3 per cent were of that class, about 30 per cent were abundant long, 16 per cent few, and less than 1 per cent absent.

Parental kernels described as having few basal hairs produced progeny of which the basal hairs on less than 1 per cent were classed as abundant long, on about 46 per cent as abundant midlength, on 46 per cent as few, and on about 7 per cent as absent.

The progeny of parental kernels described as having basal hairs absent were distributed about as follows: 62 per cent absent, 36 per cent few, 2 per cent abundant midlength, and less than 1 per cent abundant long.

TABLE V.—*Data on inheritance of basal hairs in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1920*

Strain number and basal hairs in parent kernels [a]	Basal hairs in progeny							
	Number of kernels with hairs—				Percentage of kernels with hairs—			
	Abundant		Few	Absent	Abundant		Few	Absent
	Long	Mid-length			Long	Mid-length		
AKRON FIELD STATION								
Kansas No. 5020:								
Abundant	46	52	25	2	36.8	41.6	20.0	1.6
Few	0	127	102	21	0	50.8	40.8	8.4
Absent	5	245	1,006	1,330	.2	9.5	38.9	51.4
Kansas No. 5211:								
Abundant	500	188	47	74	61.8	23.2	5.8	9.2
Few	77	542	905	18	5.0	35.1	58.7	1.2
Absent	21	916	2,643	3,806	.3	12.4	35.8	51.5
Kansas No. 5220:								
Few	0	77	4	0	0	95.1	4.9	0
Absent	0	19	801	733	0	1.2	51.6	47.2
Kansas No. 6004:								
Few	0	115	33	0	0	77.7	22.3	0
Absent	0	27	253	736	0	2.7	24.9	72.4
Kansas No. 6052:								
Absent	0	0	951	2,409	0	0	28.3	71.7
Kansas No. 6076:								
Abundant	0	57	18	1	0	75.0	23.7	1.3
Few	0	0	63	25	0	0	71.6	28.4
Absent	0	5	444	1,438	0	.3	23.5	76.2
Kansas No. 6090:								
Abundant	0	29	2	0	0	93.5	6.5	0
Few	0	467	109	28	0	77.3	18.1	4.6
Absent	0	471	1,128	1,334	0	16.1	38.4	45.5
Kansas No. 6094:								
Abundant	0	264	37	0	0	87.7	12.3	0
Few	0	282	166	0	0	62.9	37.1	0
Absent	0	154	423	1,248	0	8.4	23.2	68.4
All strains:								
Abundant	546	590	129	77	40.7	44.0	9.6	5.7
Few	77	1,610	1,381	92	2.4	50.9	43.7	2.9
Absent	26	1,837	7,649	13,034	.1	8.2	33.9	57.8
KANSAS AGRICULTURAL EXPERIMENT STATION								
Kansas No. 5020:								
Abundant	0	70	56	38	0	42.7	34.1	23.2
Few	0	25	88	13	0	19.9	69.8	10.3
Absent	0	34	569	750	0	2.5	42.1	55.4
Kansas No. 5211:								
Abundant	3	21	55	0	3.8	26.6	69.6	0
Few	2	129	245	31	.5	31.7	60.2	7.6
Absent	55	122	696	700	3.5	7.8	44.2	44.5
Kansas No. 5219:								
Abundant	0	0	21	0	0	0	100.0	0
Few	29	41	25	18	25.7	36.3	22.1	15.9
Absent	0	159	1,166	445	0	9.0	65.9	25.1
Kansas No. 5220:								
Few	0	20	46	9	0	26.7	61.3	12.0
Absent	0	12	280	512	0	1.5	34.8	63.7
Kansas No. 6004:								
Few	0	0	5	20	0	0	20.0	80.0
Absent	0	0	360	552	0	0	39.5	60.5
Kansas No. 6052:								
Absent	0	0	302	1,119	0	0	21.3	78.7
Kansas No. 6076:								
Absent	0	0	409	586	0	0	41.1	58.9
Kansas No. 6090:								
Abundant	0	4	25	1	0	13.3	83.3	3.4
Few	0	84	198	29	0	27.0	63.7	9.3
Absent	0	43	342	635	0	4.2	33.5	62.3

[a] No differentiation was made between the long and midlength subclasses of basal hairs in describing the kernels sown in 1920.

TABLE V.—*Data on inheritance of basal hairs in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1920*—Continued

Strain number and basal hairs in parent kernels *	Basal hairs in progeny							
	Number of kernels with hairs—				Percentage of kernels with hairs—			
	Abundant		Few	Absent	Abundant		Few	Absent
	Long	Mid-length			Long	Mid-length		
KANSAS AGRICULTURAL EXPERIMENT STATION—continued								
Kansas No. 6094:								
Abundant	0	41	1	0	0	97.6	2.4	0
Few	0	18	48	8	0	24.3	64.9	10.8
Absent	0	63	297	407	0	8.2	38.7	53.1
All strains:								
Abundant	3	136	158	39	.9	40.5	47.0	11.6
Few	31	317	655	128	2.8	28.0	57.9	11.3
Absent	55	433	4,421	5,706	.5	4.1	41.6	53.8
BOTH STATIONS								
Abundant	549	726	287	116	32.7	43.3	17.1	6.9
Few	108	1,927	2,036	220	2.5	44.9	47.5	5.1
Absent	81	2,270	12,070	18,740	.3	6.8	36.4	56.5

* No differentiation was made between the long and midlength subclasses of basal hairs in describing the kernels sown in 1920.

The results obtained in the study of the basal-hair character in Burt oat indicate that the abundant long hairs probably are a recessive character. Apparently several factors are involved in the production of the various classes of basal hairs, or, if determined by a single main factor, several modifiers possibly are involved. The data indicate that the absence of basal hairs is partially dominant over their presence in the Burt oat. This conclusion is in accord with the results obtained by Nilsson-Ehle (*91*), Zade (*153*), Surface (*127*), Love and Craig (*70*), and Fraser (*37*). The last named investigator obtained results which are very interesting in this connection. He observed that short basal hairs or no basal hairs are dominant over midlength basal hairs and obtained a ratio in F_2 of three of the former to one of the latter.

AWNS

The awns found in these strains of the Burt oat were classified as twisted, nontwisted, and absent. The nontwisted class was further subdivided into long and short. Data obtained in 1920 and in 1921 are presented separately.

STUDY IN 1920

The material from which the kernels used in starting these experiments was selected was machine threshed and many awns were broken off. For this reason, only the presence or absence of awns was recorded for the kernels sown at Manhattan in 1920. Hence there are no data on the inheritance of awns at the Kansas station in that year. However, the kernels sown at Akron in 1920 were selected with special reference to the awn and were described for this character.

In the classification of the parental material sown at Akron in 1920 only three awn classes were recognized. These were twisted, nontwisted, and absent. In the nontwisted class were included the two subclasses later described in the progeny as long and short. These two subclasses grade into one another in such a way as to make exact classification very difficult. Fraser (*37*) has included them in his "weak" awn class and uses the term "strong" awn to describe the class here called twisted.

Four awn groups were recognized in the classification of the progeny kernels grown at Akron in 1920, namely, twisted, nontwisted long, nontwisted short, and absent (Pl. 3). The twisted awns were similar to, although not as strongly developed as, the type of awn found in the wild species, *Avena fatua* and *A. sterilis*. They are rather stiff, twisted at the base, and more or less geniculate. The twisted lower portion of this awn is composed of alternate stripes of dark and light colored tissue.

TABLE VI.—*Data on inheritance of basal hairs in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1921*

Strain number and basal hairs in parent kernels	Basal hairs in progeny							
	Number of kernels with hairs—				Percentage of kernels with hairs—			
	Abundant		Few	Absent	Abundant		Few	Absent
	Long	Mid-length			Long	Mid-length		
AKRON FIELD STATION								
Kansas No. 5020:								
Abundant long	153	10	0	0	93.9	6.1	0	0
Few	0	84	437	47	0	14.8	76.9	8.3
Absent	0	0	175	146	0	0	54.5	45.5
Kansas No. 5211:								
Abundant long	339	16	0	0	95.5	4.5	0	0
Abundant midlength	101	322	79	5	19.9	63.5	15.6	1.0
Few	14	572	203	28	1.7	70.0	24.8	3.4
Absent	8	83	303	1,078	.6	5.6	20.6	73.2
Kansas No. 5220:								
Abundant midlength	0	83	8	0	0	91.2	8.8	0
Few	0	2	232	18	0	.8	92.1	7.1
Absent	0	0	103	120	0	0	46.2	53.8
Kansas No. 6004:								
Absent	0	0	7	22	0	0	24.1	75.9
Kansas No. 6052:								
Few	0	0	62	15	0	0	80.5	19.5
Absent	0	0	210	51	0	0	80.5	19.5
Kansas No. 6076:								
Abundant midlength	0	0	3	3	0	0	50.0	50.0
Few	0	57	205	18	0	20.4	73.2	6.4
Absent	0	3	107	141	0	1.2	42.6	56.2
Kansas No. 6090:								
Abundant midlength	0	221	5	0	0	97.8	2.2	0
Few	0	159	68	7	0	67.9	29.1	3.0
Absent	0	0	140	136	0	0	50.7	49.3
Kansas No. 6094:								
Abundant midlength	6	124	1	0	4.6	94.6	.8	0
Few	0	121	38	3	0	74.7	23.5	1.8
Absent	0	19	157	39	0	8.8	73.0	18.2
All strains:								
Abundant long	492	26	0	0	95.0	5.0	0	0
Abundant midlength	107	750	96	8	11.1	78.1	10.0	.8
Few	14	995	1,245	136	.6	41.6	52.1	5.7
Absent	8	105	1,202	1,733	.3	3.4	39.4	56.9
KANSAS AGRICULTURAL EXPERIMENT STATION								
Kansas No. 5020:								
Abundant midlength	179	50	141	0	48.4	13.5	38.1	0
Few	0	250	212	29	0	50.9	43.2	5.9
Absent	0	0	15	388	0	0	3.7	96.3
Kansas No. 5211:								
Abundant midlength	0	292	13	0	0	95.7	4.3	0
Few	0	297	40	0	0	88.1	11.9	0
Absent	0	2	235	558	0	.2	29.6	70.2
Kansas No. 5219:								
Abundant midlength	378	137	18	0	70.9	25.7	3.4	0
Few	0	1,088	440	26	0	70.0	28.3	1.7
Absent	0	41	478	599	0	3.7	42.7	53.6
Kansas No. 5220:								
Abundant midlength	0	36	39	2	0	46.8	50.6	2.6
Few	0	0	81	128	0	0	38.8	61.2
Absent	0	0	145	415	0	0	25.9	74.1
Kansas No. 6004:								
Absent	0	2	220	533	0	.3	29.1	70.6
Kansas No. 6052:								
Few	0	0	349	65	0	0	84.3	15.7
Absent	0	0	423	33	0	0	92.8	7.2
Kansas No. 6076:								
Absent	0	0	32	299	0	0	9.7	90.3
Kansas No. 6090:								
Abundant midlength	75	51	93	6	33.3	22.7	41.3	2.7
Few	0	184	196	24	0	45.5	48.5	5.9
Absent	0	0	71	282	0	0	20.1	79.9

TABLE VI.—*Data on inheritance of basal hairs in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1921*—Continued

Strain number and basal hairs in parent kernels [a]	Basal hairs in progeny							
	Number of kernels with hairs—				Percentage of kernels with hairs—			
	Abundant		Few	Absent	Abundant		Few	Absent
	Long	Mid-length			Long	Mid-length		
KANSAS AGRICULTURAL EXPERIMENT STATION—continued								
Kansas No. 6094:								
Few	0	0	254	33	0	0	88.5	11.5
Absent	0	0	192	329	0	0	36.9	63.1
All strains:								
Abundant midlength	632	566	304	8	41.9	37.5	20.1	.5
Few	0	1,819	1,572	305	0	49.2	42.5	8.3
Absent	0	45	1,811	3,436	0	.9	34.2	64.9
BOTH STATIONS								
Abundant long	492	36	0	0	95.0	5.0	0	0
Abundant midlength	739	1,316	400	16	29.9	53.3	16.2	.6
Few	14	2,814	2,817	441	.2	46.2	46.3	7.3
Absent	8	150	3,013	5,169	.1	1.8	36.1	62.0

There is much variation in the number of twists and the length of the twisted portion. This type of awn is illustrated in Plate 3, A.

Of the nontwisted class, the awns in the long subclass often were fully as long as the twisted awns, but did not show the twisting of the lower portion or any geniculation. The nontwisted long awn is illustrated in Plate 3, B. The nontwisted short subclass was more variable than any other class. Awns placed in this subclass varied from a fairly well developed awn about 15 mm. in length down to very short bristlelike appendages, almost invisible to the naked eye. Kernels having the short awns are shown in Plate 3, C. When no awns were found, they were described as absent. Awnless kernels are shown in Plate 3, D.

The data on awns in the 1920 progeny are presented in Table VII. They indicate that all types of awns were found in the progeny of each parental awn class. As a rule, however, parental kernels in each awn class had a tendency to produce a greater number of progeny kernels of the parental class than of any of the other classes. Parental kernels having twisted awns produced progenies having twisted awns on about 56 per cent of the kernels, nontwisted long awns on 10 per cent, nontwisted short on 5 per cent, and awns absent on 30 per cent. In the progenies of the parental nontwisted class about 15 per cent of the awns were described as nontwisted long, 55 per cent as nontwisted short, 19 per cent absent, and about 11 per cent twisted. The parental kernels described as having awns absent produced progenies in which the awns of about 69 per cent of the kernels were described as absent, 13 per cent as nontwisted short, 8 per cent as nontwisted long, and 10 per cent as twisted.

An examination of the data for each of the strains given in Table VII shows that in four of the seven strains in which parental kernels having the twisted awns were found, from 50.5 to 86.3 per cent of the progeny kernels were described as having awns of that class. In Kansas No. 6004 only 21.2 per cent and in Kansas No. 6052 only 26.4 per cent of the progeny kernels grown from parental kernels with twisted awns were described as having twisted awns. As the two awn subclasses later described as nontwisted long and short were not separated in describing the parental kernels from which the 1920 crop was grown, the progenies representing these two subclasses may be considered together in discussing the results obtained in 1920. If this be done it is seen that in three of the strains the kernels having nontwisted awns produced rather high

TABLE VII.—*Data on inheritance of twisted, nontwisted (long and short), and absent awns in eight strains of Burt oat grown at the Akron Field Station in 1920*

Strain number and awn class in parent kernels *	Awn classes in progeny							
	Number of kernels with awns—				Percentage of kernels with awns—			
	Twisted	Nontwisted		Absent	Twisted	Nontwisted		Absent
		Long	Short			Long	Short	
Kansas No. 5020:								
Twisted	114	33	10	69	50.5	14.6	4.4	30.5
Nontwisted	107	158	562	233	10.1	14.9	53.0	22.0
Absent	166	158	194	1,157	9.9	9.4	11.6	69.1
Kansas No. 5211:								
Twisted	562	26	30	143	73.9	3.4	3.9	18.8
Nontwisted	458	815	3,602	661	8.3	14.7	65.1	11.9
Absent	389	289	557	2,105	11.6	8.7	16.7	63.0
Kansas No. 5220:								
Nontwisted	46	87	168	87	11.9	22.4	43.3	22.4
Absent	120	208	237	681	9.6	16.7	19.0	54.7
Kansas No. 6004:								
Twisted	18	12	26	29	21.2	14.1	30.6	34.1
Nontwisted	34	86	115	283	6.6	16.6	22.2	54.6
Absent	14	15	6	524	2.5	2.7	1.1	93.7
Kansas No. 6032:								
Twisted	138	82	31	271	26.4	15.7	5.9	51.9
Nontwisted	274	81	45	302	39.0	11.6	6.4	43.0
Absent	308	115	99	1,614	14.4	5.4	4.6	75.6
Kansas No. 6076:								
Twisted	141	75	14	138	38.3	20.4	3.8	37.5
Nontwisted	93	51	54	111	30.1	16.5	17.5	35.9
Absent	7	80	106	1,181	.5	5.8	7.7	86.0
Kansas No. 6090:								
Twisted	129	3	2	72	62.6	1.5	1.0	34.9
Nontwisted	53	324	1,077	303	3.0	18.4	61.3	17.3
Absent	74	87	294	1,150	4.6	5.4	18.3	71.7
Kansas No. 6094:								
Twisted	308	11	3	35	86.3	3.1	0.8	9.8
Nontwisted	163	137	654	179	14.4	12.1	57.7	15.8
Absent	211	88	187	597	19.5	8.1	17.3	55.1
All strains:								
Twisted	1,410	242	116	757	55.8	9.6	4.6	30.0
Nontwisted	1,228	1,739	6,377	2,159	10.7	15.1	55.4	18.8
Absent	1,289	1,040	1,682	9,009	9.9	8.0	12.9	69.2

* No differentiation was made between the long and the short nontwisted awns in describing the parent kernels.

percentages of each of the two extreme classes, namely, twisted and absent. In five of the eight strains parental kernels described as having nontwisted awns produced progeny of which the majority had the same type of awns.

Taking all strains together, the parental kernels described as having nontwisted awns produced 70.5 per cent of progeny kernels with nontwisted awns. The kernels described as having awns absent bred true to about as great an extent. In each of the eight strains over 50 per cent of the progeny of these kernels were awnless and the average for all strains was 69.2 per cent.

The data obtained in 1920 on the inheritance of awns indicate that parental kernels of the three classes reproduced their awn class in at least 50 per cent of their progeny. However, all classes of awns were produced in the progeny of each of the parental classes in all of the strains grown.

STUDY IN 1921

The data on the inheritance of awns in 1921 are presented in Table VIII. The twisted awn appears to breed comparatively true. Occasionally, probably for physiological reasons, kernels which carry the gene for twisted awns fail to produce any awns or awns as large as would be expected. In describing about 60,000 kernels of Burt oat the writers have observed that the twisted awn occasionally does not reach its full development until a rather late stage in the maturity of the plant and if unfavorable conditions prevent the normal maturing of the plant the development of the awn also is affected.

The awns described as nontwisted long apparently are unstable in breeding behavior, segregating into all classes ranging from twisted to absent. Parental kernels having nontwisted long awns produced about 74 per cent of such kernels in their progenies. The long and short subclasses grade into one another, making classification extremely difficult in many cases.

Parental kernels with nontwisted short awns produced 28.9 per cent of short-awned kernels and only 6.1 per cent of the twisted-awned kernels in their progenies, while parental kernels with the nontwisted long awns produced 7.2 and 14.9 per cent, respectively. From this it appears that these two subclasses, that is, the long and short awned, are somewhat different genetically. Kernels with awns absent reproduced that character in 59.3 per cent of the progenies, while 4.4 and 20.9 per cent, respectively, were nontwisted short and nontwisted long and 15.4 per cent were twisted.

In general the results on the inheritance of awns obtained by the writers correspond with those of previous investigators, except that previous workers have not differentiated between nontwisted long and short awns. In the Burt oat the absent or awnless condition seems partially dominant, while the twisted awn seems recessive. The influence of physiological and other factors may account for the fact that some kernels which apparently carry the gene for producing awns failed to produce them. The possible influence of environmental factors on the development of awns in oats has been recognized by several other investigators.

Awns are readily observable and have been studied by more investigators than have some of the other characters of the oat spikelet. Nilsson-Ehle (*95*) states that certain yellow oats carry an inhibitor for awns. Fraser (*37*) in studying the cross Burt × Sixty-Day found no evidence of the existence of such an inhibiting factor in the Burt variety, but his ideas were in agreement with those of Nilsson-Ehle with respect to the presence of an awn-inhibiting factor in yellow oat kernels in the Sixty-Day variety. In the crossing experiments of Zade (*153*), Nilsson-Ehle (*91*, *93*), Surface (*127*), Love and Craig (*70*), Love and Fraser (*69*), and Fraser (*37*), it was found as a rule that in crosses of awned × awnless oats the F_1 was intermediate and in F_2 the fully awned type behaved as a recessive. Fraser (*37*) reports that in the cross of Burt, which he states was usually awned, and Sixty-Day awnless, he found nearly complete dominance of the awnless type in F_1.

LEMMA COLOR

The color of the oat lemma probably is the most complex of all of the characters considered. This is due in part to its being much more easily affected by physiological and climatic conditions than most of the other characters, which are morphological. In its genetic basis also lemma color in the Burt oat is certainly very complex, perhaps more so than any of the other spikelet characters studied. The color of the lemma is not fully developed until the kernel approaches maturity. Hence any condition which interferes with normal ripening has a marked effect on the color and makes it one of the most difficult oat characters to classify accurately. For these reasons it may be considered less important from the genetic and taxonomic standpoint, although it is perhaps the character with which agronomists, grain inspectors, seedsmen, and farmers are most familiar.

The lemma color in the progenies grown was described as black, dark brown, light brown, red, yellow, and white. An incomplete series of kernel colors is shown in Plates 4 to 6, inclusive. The names of the color classes used in the text and in the tables are those commonly recognized by agronomists. The colors graded into one another, and often it was extremely difficult to determine the correct color classification. This was especially true of the lighter colored kernels.

STUDY IN 1920

In the classification of the parental material at Akron in 1920 a class termed "variegated" was created for those kernels showing a more or less mottled color. Very few variegated kernels were found in the progenies harvested in 1920, apparently proving that variegation resulted from climatic conditions or physiological causes. For this reason the variegated class was no longer used. Data were obtained in only two of the eight strains on the 1920 progeny kernels from parental kernels described as variegated. In describing the original material no distinction was made at either station between the dark and light shades of brown. In describing the 1920 progenies from the Manhattan station and one strain, Kansas No. 5220, from the Akron station, no distinction was made between the two shades of brown. This differentiation was made in the other seven strains grown at Akron in 1920.

A few grayish-brown kernels were observed in the course of the experiments, but as they were not of frequent

TABLE VIII.—*Data on inheritance of twisted, nontwisted (long and short), and absent awns in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1921*

Strain number and awn class in parent kernels	Awn classes in progeny							
	Number of kernels with awns—				Percentage of kernels with awns—			
	Twisted	Nontwisted		Absent	Twisted	Nontwisted		Absent
		Long	Short			Long	Short	
AKRON FIELD STATION								
Kansas No. 5020:								
Twisted	91	20	11	19	64.5	14.2	7.8	13.5
Nontwisted long	52	63	28	16	32.7	39.6	17.6	10.1
Nontwisted short	23	130	70	20	9.5	53.5	28.8	8.2
Absent	15	95	44	355	2.9	18.7	8.6	69.7
Kansas No. 5211:								
Twisted	384	15	0	10	93.9	3.7	0	2.4
Nontwisted long	44	49	7	8	40.7	45.4	6.5	7.4
Nontwisted short	70	822	372	142	5.0	58.5	26.4	10.1
Absent	198	249	40	741	16.1	20.3	3.3	60.3
Kansas No. 5220:								
Twisted	5	1	0	1	71.4	14.3	0	14.3
Nontwisted long	34	42	7	24	31.8	39.3	6.5	22.4
Nontwisted short	13	83	37	29	8.0	51.2	22.9	17.9
Absent	13	39	10	228	4.5	13.4	3.5	78.6
Kansas No. 6004:								
Absent	7	2	1	19	24.1	6.9	3.5	65.5
Kansas No. 6052:								
Nontwisted short	29	33	3	12	37.7	42.8	3.9	15.6
Absent	28	12	10	211	10.7	4.6	3.8	80.9
Kansas No. 6076:								
Twisted	83	2	0	3	94.3	2.3	0	3.4
Nontwisted long	0	58	23	0	0	71.6	28.4	0
Nontwisted short	0	42	75	2	0	35.3	63.0	1.7
Absent	67	25	16	141	26.9	10.1	6.4	56.6
Kansas No. 6090:								
Twisted	63	0	0	2	96.9	0	0	3.1
Nontwisted long	0	50	30	0	0	62.5	37.5	0
Nontwisted short	3	173	157	43	.8	46.0	41.8	11.4
Absent	3	23	21	168	1.4	10.7	9.8	78.1
Kansas No. 6094:								
Twisted	47	0	1	2	94.0	0	2.0	4.0
Nontwisted short	1	87	37	6	.8	66.4	28.2	4.6
Absent	40	163	41	83	12.2	49.9	12.5	25.4
All strains:								
Twisted	673	38	12	37	88.5	5.0	1.6	4.9
Nontwisted long	130	262	95	48	24.3	49.0	17.7	9.0
Nontwisted short	139	1,370	751	254	5.5	54.5	29.9	10.1
Absent	371	608	183	1,946	11.9	19.6	5.9	62.6
KANSAS AGRICULTURAL EXPERIMENT STATION								
Kansas No. 5020:								
Twisted	200	0	0	0	100.0	0	0	0
Nontwisted long	3	0	0	0	100.0	0	0	0
Nontwisted short	0	105	76	2	0	57.4	41.5	1.1
Absent	26	101	12	311	5.8	22.4	2.7	69.1
Kansas No. 5211:								
Twisted	654	148	0	9	80.6	18.3	0	1.1
Nontwisted long	53	217	7	5	18.8	76.9	2.5	1.8
Kansas No. 5219:								
Twisted	283	26	5	36	80.9	7.4	1.4	10.3
Nontwisted long	204	911	75	13	17.0	75.7	6.2	1.1
Nontwisted short	40	152	26	34	15.9	60.3	10.3	13.5
Absent	165	127	14	167	34.9	26.8	3.0	35.3
Kansas No. 5220:								
Twisted	119	50	2	6	67.2	28.3	1.1	3.4
Nontwisted long	32	278	11	24	9.3	80.6	3.2	6.9
Absent	68	113	3	8	35.4	58.8	1.6	4.2
Kansas No. 6004:								
Twisted	260	130	3	109	51.8	25.9	.6	21.7
Nontwisted long	30	45	1	2	38.4	57.7	1.3	2.6
Absent	3	59	0	91	1.9	38.6	0	59.5

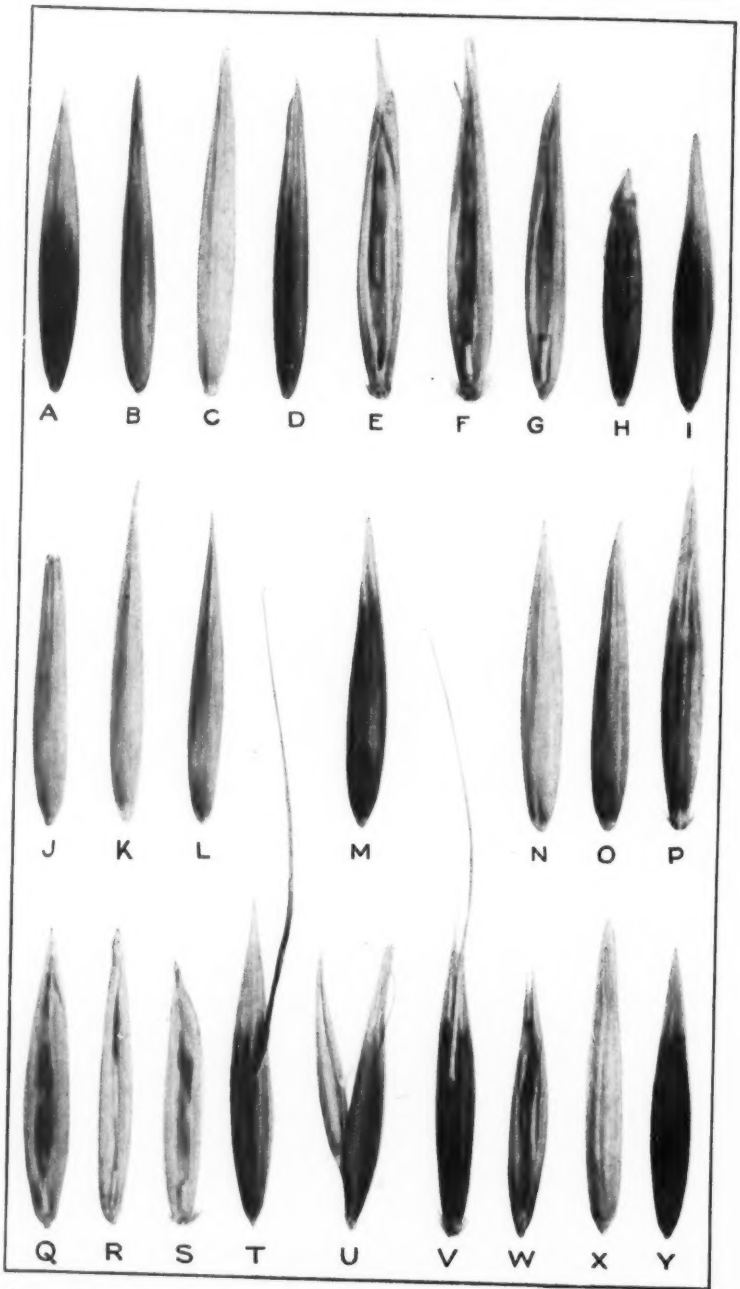
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TABLE VIII.—*Data on inheritance of twisted, nontwisted (long and short), and absent awns in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1921*—Continued

Strain number and awn class in parent kernels	Awn classes in progeny							
	Number of kernels with awns—				Percentage of kernels with awns—			
	Twisted	Nontwisted		Absent	Twisted	Nontwisted		Absent
		Long	Short			Long	Short	
KANSAS AGRICULTURAL EXPERIMENT STATION—continued								
Kansas No. 6052:								
Twisted	692	45	4	32	89.5	5.8	0.5	4.2
Absent	115	5	2	6	89.8	3.9	1.6	4.7
Kansas No. 6076:								
Twisted	153	0	0	0	100.0	0	0	0
Kansas No. 6090:								
Nontwisted long	1	396	31	22	.2	88.0	6.9	4.9
Absent	0	4	0	349	0	1.1	0	98.9
Kansas No. 6094:								
Twisted	602	60	0	0	90.9	9.1	0	0
Nontwisted long	2	160	1	0	1.2	98.2	.6	0
All strains:								
Twisted	2,963	459	14	192	81.7	12.6	.4	5.3
Nontwisted long	325	2,007	126	66	12.9	79.5	5.0	2.6
Nontwisted short	40	257	102	36	9.2	59.1	23.4	8.3
Absent	377	409	31	932	21.6	23.4	1.8	53.3
BOTH STATIONS								
Twisted	3,636	497	26	229	82.9	11.3	.6	5.2
Nontwisted long	455	2,269	221	114	14.9	74.2	7.2	3.7
Nontwisted short	179	1,627	853	290	6.1	55.2	28.9	9.8
Absent	748	1,017	214	2,878	15.4	20.9	4.4	59.3

occurrence and could not always be clearly distinguished from the kernels classed as light brown, no separate classification was made for them. It is possible that some of the kernels included in the variegated and red classes should have been classed as gray. Kernels having a grayish-brown color are shown in Plate 6, P.

The data on the inheritance of kernel color are presented in Table IX. In general, the dark-colored kernels produced mostly dark-colored progeny, while the light-colored kernels tended to produce light-colored kernels in their progenies. The black parental kernels produced mostly dark-brown and black progeny kernels and a comparatively small percentage of light brown and red kernels. Brown kernels largely produced brown kernels of different shades and also about 26 per cent of reds and a few yellows. Red parental kernels produced about 69 per cent of red kernels in their progenies. Yellow kernels produced about 81 per cent of red kernels, and white parental kernels produced mostly red and yellow kernels in their progenies. While none of the colors appeared constant in breeding behavior, there was a rather definite relation between the color of the parental and progeny kernels.

EXPLANATORY LEGEND FOR PLATE 6

Lemma colors of 7 strains of Burt oat in 1920. A to C.—Kansas No. 5219: A, very dark brown, yellow tipped; B, reddish brown; C, yellowish white. D.—Kansas No. 6094, light brown. E.—Kansas No. 5020, light yellowish brown. F to G.—Kansas No. 5211: F, light yellowish brown; G, light brownish yellow. H to N.—Kansas No. 5020: H, very dark gray; I, dark gray; J, grayish yellow; K, grayish white; L, light grayish yellow; M, dark grayish brown; N, grayish white. O.—Kansas No. 6076, grayish yellow. P.—Kansas No. 5020, grayish brown, streaked. Q.—Kansas No. 5211, light brownish yellow. R.—Kansas No. 6052, yellowish white. S.—Kansas No. 6094, light grayish yellow. T.—Kansas No. 6052, dark grayish brown. U.—Kansas No. 6090, light brown. V.—Kansas No. 5219, dark brown. W.—Kansas No. 5211, light brown. X.—Kansas No. 6052, light yellowish white. Y.—Kansas No. 5219, very dark brown.

TABLE IX.—*Data on inheritance of lemma color in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1920*

Strain number and color of parent kernels	Color of lemmas in lower florets of progeny													
	Number of lemmas—							Percentage of lemmas—						
	Black	Dark brown	Brown[a]	Light brown	Red	Yellow	White	Black	Dark brown	Brown[a]	Light brown	Red	Yellow	White
AKRON FIELD STATION														
Kansas No. 5020:														
Black	67	189		0	0	0	0	26.2	73.8		0	0	0	0
Brown	15	177		170	170	0	0	2.8	33.2		32.0	32.0	0	0
Red	0	28		62	929	15	0	0	2.7		6.0	89.8	1.5	0
Yellow	0	0		0	639	17	0	0	0		0	97.4	2.6	0
White	0	0		0	460	23	0	0	0		0	95.2	4.8	0
Kansas No. 5211:														
Black	89	555		0	32	0	0	13.2	82.1		0	4.7	0	0
Brown	90	571		180	259	0	0	8.2	51.9		16.4	23.5	0	0
Red	0	75		233	2,281	179	0	0	2.7		8.4	82.4	6.5	0
Yellow	0	0		138	2,108	349	37	0	0		5.2	80.1	13.3	1.4
White	0	0		11	736	849	188	0	0		.6	41.3	47.6	10.5
Variegated[b]	0	0		1	673	103	0	0	0		.1	86.6	13.3	0
Kansas No. 5220:														
Black	100	0	129	0	0	0	0	43.7	0	56.3	0	0	0	0
Brown	42	0	114	0	0	0	0	26.9	0	73.1	0	0	0	0
Red	0	0	85	0	348	452	0	0	0	9.6	0	39.3	51.1	0
Yellow	0	0	13	0	120	152	0	0	0	4.6	0	42.1	53.3	0
White	20	0	30	0	1	3	25	25.3	0	38.0	0	1.3	3.8	31.6
Kansas No. 6004:														
Brown	0	0		0	192	0	0	0	0		0	100.0	0	0
Red	0	0		0	410	23	0	0	0		0	94.7	5.3	0
Yellow	0	0		0	374	17	0	0	0		0	95.7	4.3	0
White	0	0		0	143	5	0	0	0		0	96.6	3.4	0
Kansas No. 6052:														
Black	35	44		0	0	0	0	44.3	55.7		0	0	0	0
Brown	0	93		27	119	41	0	0	33.2		9.6	42.5	14.6	0
Red	0	0		0	219	120	1	0	0		0	64.4	35.3	.3
Yellow	0	0		1	1,841	146	0	0	0		.1	92.6	7.3	0
White	0	0		0	392	271	10	0	0		0	58.2	40.3	1.5
Kansas No. 6076:														
Black	17	41		10	0	0	0	25.0	60.3		14.7	0	0	0
Brown	18	41		17	266	0	0	5.3	12.0		4.9	77.8	0	0
Red	0	0		0	438	2	0	0	0		0	99.5	.5	0
Yellow	0	0		0	453	27	0	0	0		0	94.4	5.6	0
White	0	0		0	596	122	3	0	0		0	82.7	16.9	.4

Kansas No. 6090:														
Black	43	633		23	101	0	0	5.4	79.1		2.9	12.6	0	0
Brown	12	1,105		78	131	9	0	.9	82.8		5.8	9.8	.7	0
Red	0	316		89	375	0	0	0	40.5		11.4	48.1	0	0
Yellow	0	8		59	245	36	0	0	2.3		17.0	70.4	10.3	0
White	0	154		6	135	10	0	0	50.5		2.0	44.2	3.3	0
Kansas No. 6094:														
Black	0	220		3	25	0	0	0	88.7		1.2	10.1	0	0
Brown	0	229		0	154	1	0	0	59.6		0	40.1	.3	0
Red	0	25		0	590	22	0	0	3.9		0	92.6	3.5	0
Yellow	0	0		0	626	71	23	0	0		0	86.9	9.9	3.2
White	0	0		0	440	94	0	0	0		0	82.4	17.6	0
Variegated [b]	0	25		0	25	0	0	0	50.0		0	50.0	0	0
All strains:														
Black	351	1,682	129	36	158	0	0	14.9	71.4	5.5	1.5	6.7	0	0
Brown [a]	177	2,216	114	472	1,291	51	0	4.1	51.3	2.6	10.9	29.9	1.2	0
Red	0	444	85	384	5,590	813	1	0	6.1	1.2	5.2	76.4	11.1	0
Yellow	0	8	13	198	6,406	815	60	0	.1	.2	2.6	85.4	10.9	.8
White	20	154	30	17	2,903	1,377	226	.4	3.3	.6	.4	61.4	29.1	4.8
Variegated [b]	0	25	0	1	698	103	0	0	3.0	0	.1	84.4	12.5	0
KANSAS AGRICULTURAL EXPERIMENT STATION														
Kansas No. 5020:														
Brown	27		644		81	0	0	3.6		85.6		10.8	0	0
Red	0		155		79	14	3	0		61.7		31.5	5.6	1.2
Yellow	0		94		216	13	0	0		29.1		66.9	4.0	0
White	0		101		168	45	3	0		31.9		53.0	14.2	.9
Kansas No. 5211:														
Black	0		33		27	0	0	0		55.0		45.0	0	0
Brown	50		755		475	29	0	3.8		57.7		36.3	2.2	0
Yellow	0		80		297	39	0	0		19.2		71.4	9.4	0
White	0		86		115	73	0	0		31.4		42.0	26.6	0
Kansas No. 5219:														
Black	4		20		0	0	0	16.7		83.3		0	0	0
Brown	33		502		182	1	0	4.6		69.9		25.4	.1	0
Red	0		152		128	9	0	0		52.6		44.3	3.1	0
White	3		576		241	53	0	.3		66.0		27.6	6.1	0
Kansas No. 5220:														
Black	4		13		1	0	0	22.2		72.2		5.6	0	0
Brown	9		294		223	90	1	1.5		47.6		36.1	14.6	.2
Red	0		12		90	34	0	0		8.8		66.2	25.0	0
Yellow	0		0		75	6	0	0		0		92.6	7.4	0
White	0		0		22	1	4	0		0		81.5	3.7	14.8
Kansas No. 6004:														
Yellow	0		69		366	28	0	0		14.9		79.0	6.1	0
White	0		179		217	78	0	0		37.8		45.8	16.4	0

[a] In 1 strain, Kansas No. 5220, grown at Akron and in all 9 strains grown at Manhattan in 1920, all brown lemmas were recorded as brown, instead of being separated into dark brown and light brown as was done in describing the other 7 strains grown at Akron.

[b] In only 2 strains, Kansas Nos. 5211 and 6094, were the progeny kernels from parental kernels classed as "variegated" included at Akron.

TABLE IX.—*Data on inheritance of lemma color in 9 strains of Burt oat grown at the Akron Field Station and at the Kansas Agricultural Experiment Station in 1920*—Continued

Strain number and color of parent kernels	Color of lemmas in lower florets of progeny													
	Number of lemmas—							Percentage of lemmas—						
	Black	Dark brown	Brown[a]	Light brown	Red	Yellow	White	Black	Dark brown	Brown[a]	Light brown	Red	Yellow	White
KANSAS AGRICULTURAL EXPERIMENT STATION—continued.														
Kansas No. 6052:														
Brown	0		26		8	0	0	0		76.5		23.5	0	0
Red	0		285		469	348	16	0		25.5		42.0	31.1	1.4
Yellow	0		12		40	22	0	0		16.2		54.1	29.7	0
White	0		65		88	42	0	0		33.3		45.1	21.6	0
Kansas No. 6076:														
Brown	0		62		0	0	0	0		100.0		0	0	0
Red	11		60		18	0	0	12.4		67.4		20.2	0	0
Yellow	0		46		139	189	0	0		12.3		37.2	50.5	0
White	0		25		156	289	0	0		5.3		33.2	61.5	0
Kansas No. 6090:														
Black	3		47		0	0	0	6.0		94.0		0	0	0
Brown	32		952		51	11	0	3.1		91.0		4.9	1.0	0
Red	0		24		15	0	0	0		61.5		38.5	0	0
Yellow	0		76		30	0	0	0		71.7		28.3	0	0
White	0		88		32	0	0	0		73.3		26.7	0	0
Kansas No. 6094:														
Black	0		21		0	0	0	0		100.0		0	0	0
Brown	2		240		75	14	0	.6		72.5		22.7	4.2	0
Red	0		50		150	65	5	0		18.5		55.6	24.1	1.8
Yellow	0		0		0	32	0	0		0		0	100.0	0
White	0		28		100	101	0	0		12.2		43.7	44.1	0
All strains:														
Black	11		134		28	0	0	6.3		77.5		16.2	0	0
Brown	153		3,475		1,095	145	1	3.1		71.4		22.5	3.0	0
Red	11		738		949	470	24	.5		33.7		43.3	21.4	1.1
Yellow	0		377		1,163	329	0	0		20.2		62.2	17.6	0
White	3		1,148		1,139	682	7	.1		38.6		38.2	22.9	.2
BOTH STATIONS														
Black	362	1,682	263	36	186	0	0	14.3	66.5	10.4	1.4	7.4	0	0
Brown	330	2,216	3,589	472	2,386	196	1	3.6	24.1	39.1	5.1	26.0	2.1	0
Red	11	444	823	384	6,539	1,283	25	.1	4.7	8.6	4.0	68.8	13.5	.3
Yellow	0	8	390	198	7,569	1,144	60	0	.1	4.2	2.1	80.8	12.2	.6
White	23	154	1,178	17	4,042	2,059	233	.3	2.0	15.3	.2	52.5	26.7	3.0
Variegated[b]	0	25	0	1	698	103	0	0	3.0	0	.1	84.4	12.5	0

[a] In 1 strain, Kansas No. 5220, grown at Akron and in all 9 strains grown at Manhattan in 1920, all brown lemmas were recorded as brown, instead of being separated into dark brown and light brown as was done in describing the other 7 strains grown at Akron.

[b] In only 2 strains, Kansas Nos. 5211 and 6094, were the progeny kernels from parental kernels classed as "variegated" included at Akron.

STUDY IN 1921

Because of the injury caused by chinch bugs at Manhattan no data on kernel color are presented for the crop grown there in 1921. The data from Akron, given in Table X, indicate that some of the kernels classed as black and dark brown probably are similar in breeding behavior. The color described as dark brown in many cases probably is the result of the imperfect development of black. The results obtained in 1921 are similar to those of 1920 in that the dark-colored parental kernels show a very strong tendency to produce dark-colored kernels in their progenies.

The light brown color class probably contains many genetic reds, which, due to physiological influences, appear as light brown. The fact that the parental kernels described as light brown produced about 71 per cent of red kernels in their progenies supports this statement. Red was the most stable of the kernel colors. Red kernels produced only small percentages of other colors in their progenies. A few light brown and yellow kernels were produced in the progenies of red kernels, which may have been due in part to the effect of physiological factors, which favor an intensification in the one case and a dilution or incomplete development of red color in the other. Many parental kernels which were described as yellow apparently were genetic reds, in which the red color for some reason did not attain its normal development.

Comparatively few yellows bred true, most of them producing reds of varying intensities, and including occasional kernels described as light brown. Kernels classified as white appear to be of two classes, those which for physiological reasons did not fully develop their normal color and thus appeared white, although genetically really colored, and those which were genetically white. Comparatively few (26.2 per cent) of the kernels in the progenies of parental white kernels were described as white. It appears difficult to obtain strains of Burt oat which will breed true for white kernel color. This is not an unexpected condition when it is remembered that this variety is known to contain factors for black, several shades of brown, red, yellow, and probably gray kernel colors. It may be supposed that all of these factors would have to be absent or in the recessive condition to permit the production of homozygous white kernels.

The occurrence of dark-colored gray and brown kernels in the cross Burt (red) × Sixty-Day (yellow) is explained by Fraser (*37*) as probably due to reversion or to mutation. The results obtained in these experiments clearly indicate that the dark-colored kernels which occur in Burt oat are the result of genetic factors for dark color, carried by many strains in this variety. The advisability of assigning only two color factors for the variety Burt, as Fraser has done, is questioned, though probably he meant only to indicate that these were the particular factors considered in his experiments and not necessarily the only ones present in the variety. Further and more carefully controlled experiments are needed, for as Fraser has stated—

> Considerable variation in color is to be noted even within the same pure line during different seasons, or under strikingly different environmental conditions.

The results obtained in these experiments indicate that the Burt oat not only contains the "R" and "Y" color factors mentioned by Fraser (*37*) in the strain with which he worked but probably several additional color factors. The strain of Burt used by Fraser doubtless was a light-colored form. Most of the strains of Burt oat observed by the writers have had at least a few dark-colored kernels, including blacks or dark browns, light browns, and grays, which produced dark-colored kernels in their progenies.

ASSOCIATION OF SPIKELET CHARACTERS

An attempt was made to determine what correlation, if any, existed between the kernel characters studied. These studies were made from the original descriptions of the 1920 crop grown at Manhattan. No correlation data are presented on the material grown at Akron in 1920 nor on the material grown at either station in 1921. Studies of correlation or association were made of the following pairs of characters: (1) Floret disjunction and spikelet disarticulation, (2) spikelet disarticulation and basal hairs, (3) spikelet disarticulation and awns, (4) lemma color and spikelet disarticulation, (5) lemma color and awns.

These studies indicate very clearly that certain spikelet and floret characters "tend to go together in heredity," and that genetic coupling or linkage probably is involved. It has been thought best, however, to use the terms association and correlation in the discussion of these data, for

TABLE X.—*Data on inheritance of lemma color in 8 strains of Burt oat grown at the Akron Field Station in 1921*

Strain number and color of parent lemmas	Color of lemmas in lower florets of progeny											
	Number of lemmas—						Percentage of lemmas—					
	Black	Dark brown	Light brown	Red	Yellow	White	Black	Dark brown	Light brown	Red	Yellow	White
Kansas No. 5020:												
Black	6	154	29				3.2	81.5	15.3			
Dark brown		106	173	33				34.0	55.4	10.6		
Light brown				163						100.0		
Red			4	193	40				1.7	81.4	16.9	
Yellow				130	21					86.1	13.9	
Kansas No. 5211:												
Black			76	30					71.7	28.3		
Dark brown	60	126	104	18			19.5	40.9	33.8	5.8		
Light brown				216						100.0		
Red				641	4					99.4	.6	
Yellow			16	987	209	5			1.3	81.1	17.2	0.4
White				157	255	182				26.4	42.9	30.7
Kansas No. 5220:												
Black		9	56	13				11.5	71.8	16.7		
Light brown			101	61					62.3	37.7		
Red				39						100.0		
Yellow				227	31					88.0	12.0	
White				9	2					81.8	18.2	
Kansas No. 6004:												
Light brown				16						100.0		
Yellow					13						100.0	
Kansas No. 6052:												
Black		4	38	34	1			5.2	49.3	44.2	1.3	
Dark brown		18	151	39				8.7	72.6	18.7		
Red				22	31					41.5	58.5	
Kansas No. 6076:												
Black		123	12	8				86.0	8.4	5.6		
Dark brown		33	46					41.8	58.2			
Red		3		264	8			1.1		96.0	2.9	
Kansas No. 6090:												
Black	19	47	45				17.1	42.4	40.5			
Dark brown	4	11	49	78	3		2.7	7.6	33.8	53.8	2.1	
Light brown		8	83	12				7.8	80.6	11.6		
Red			24	278					7.9	92.1		
Yellow				71						100.0		
Kansas No. 6094:												
Dark brown		13	93	33				9.4	66.9	23.7		
Red			8	117	1				6.3	92.9	.8	
Yellow				109	16					87.2	12.8	
White				91						100.0		
SUMMARY												
All strains:												
Black	25	337	256	83	1		3.6	48.0	36.5	11.8	.1	
Dark brown	64	307	616	201	3		5.4	25.8	51.7	16.9	.2	
Light brown		8	184	468				1.2	27.9	70.9		
Red		3	36	1,554	84			.2	2.1	92.7	5.0	
Yellow			16	1,524	290	5			.9	83.0	15.8	.3
White				257	257	182				36.9	36.9	26.2

the reason that they were not obtained from controlled crosses of parents of known factorial composition for the characters under observation, the conditions usually considered essential for the accurate study of linkage relations. The data on association of kernel characters are presented in Tables XI to XV in such a way that both actual or observed numbers and percentages for each pair of characters can be seen at a glance.

In addition, the coefficient of association (Q) of Yule (*152*) has been determined for each of the five association groups. In order to use the formula,

$$Q=\frac{ad-bc}{ad+bc},$$

it was necessary to group the data for any character into two contrasting classes. Thus, in determining association between awns and kernel color, the kernels were classed as awned or

TABLE XI.—*Data on association of class of floret disjunction and spikelet disarticulation in 9 strains of Burt oat grown at the Kansas Agricultural Experiment Station in 1920*

Strain number and kind of floret disjunction	Spikelet disarticulation					
	Number of kernels disarticulating by—			Percentage of kernels disarticulating by—		
	Abscission	Semiabscission	Fracture	Abscission	Semiabscission	Fracture
Kansas No. 5020:						
Basifracture	75	88	105	28.0	32.8	39.2
Heterofracture	30	16	39	35.3	18.8	45.9
Disarticulation	104	292	894	8.1	22.6	69.3
Kansas No. 5211:						
Basifracture	312	124	175	51.1	20.3	28.6
Heterofracture	114	48	51	53.5	22.5	24.0
Disarticulation	373	260	602	30.2	21.1	48.7
Kansas No. 5219:						
Basifracture	325	302	87	45.5	42.3	12.2
Heterofracture	89	62	25	50.6	35.2	14.2
Disarticulation	323	404	287	31.9	39.8	28.3
Kansas No. 5220:						
Basifracture	41	31	58	31.5	23.9	44.6
Heterofracture	22	8	37	32.8	12.0	55.2
Disarticulation	38	130	514	5.6	19.0	75.4
Kansas No. 6004:						
Basifracture	0	5	63	0	7.4	92.6
Heterofracture	0	1	19	0	5.0	95.0
Disarticulation	0	12	837	0	1.4	98.6
Kansas No. 6052:						
Basifracture	0	2	74	0	2.6	97.4
Heterofracture	0	0	34	0	0	100.0
Disarticulation	0	19	1,292	0	1.4	98.6
Kansas No. 6076:						
Basifracture	0	27	62	0	30.3	69.7
Heterofracture	0	5	7	0	41.7	58.3
Disarticulation	0	58	836	0	6.5	93.5
Kansas No. 6090:						
Basifracture	162	102	49	51.8	32.6	15.6
Heterofracture	32	30	18	40.0	37.5	22.5
Disarticulation	153	275	540	15.8	28.4	55.8
Kansas No. 6094:						
Basifracture	52	54	46	34.2	35.5	30.3
Heterofracture	11	9	7	40.8	33.3	25.9
Disarticulation	115	208	381	16.3	29.6	54.1
All strains:						
Basifracture	967	735	719	39.9	30.4	29.7
Heterofracture	298	179	237	41.7	25.1	33.2
Disarticulation	1,106	1,658	6,183	12.4	18.5	69.1

$Q=0.672\pm0.003$

awnless, on the one hand, and as dark or light colored on the other. It is true, of course, that the coefficientof association based on this grouping gives no information as to the relations between the individual phases of the two characters. However, it is believed that the coefficient of association determined in this manner does give a reliable index of the degree of association which exists between the two characters. This method has been proposed and used in somewhat similar though not exactly comparable cases by Collins (*21*) and later by Kempton (*57*). By this method the complete independence of two character pairs is represented by 0 and complete association by 1. Intermediate degrees of relationship are expressed by the intermediate decimals.

The probable errors of the coefficients of association as given in the text and in Tables XI to XV were determined by substituting Q for r in the following formula:

$$E_r=\frac{0.6745\ (1-r^2)}{\sqrt{n}},$$

which is the one generally used for computing probable errors of correlation coefficients. While the values thus obtained are admittedly only approximations, it is believed that they do not deviate from the true values for the probable errors of Q any more than, if as much as, the values for Q itself differ from the values for r. The relations of these two constants are shown in the following table from Yule (*152*).

Corresponding values of Q and r

Q	r	Q	r
0.0	0.000	0.5	0.409
.1	.079	.6	.500
.2	.158	.7	.598
.3	.239	.8	.707
.4	.322	.9	.833
		1.0	1.000

Yule states that for corresponding values of Q and r the probable error of Q is less, not greater, than that of r, that is, if we form Q and r for the same material the probable error of the former constant is the smaller. The ratio of the standard error of Q to the standard error of r is very close, as shown in the following table taken from Yule (*152*):

Ratio of the standard error of Q to the standard error of r for equal numerical values of Q and r

Q	Ratio	Q	Ratio
0.1	1.001	0.6	1.061
.2	1.005	.7	1.095
.3	1.012	.8	1.155
.4	1.023	.9	1.283
.5	1.038	1.0	1.000

FLORET DISJUNCTION AND SPIKELET DISARTICULATION

Table XI presents the summarized data obtained in the study of the relation between floret disjunction and spikelet disarticulation. These data show clearly that some relation exists between these characters, although it is less pronounced in some of the strains than in others.

The basifracture type of floret disjunction and the abscission type of spikelet disarticulation might naturally be expected to be correlated. Similarly floret disjunction by disarticulation and spikelet disarticulation by fracture might be expected to be closely associated because these combinations are typical of the two species. If progenies of the heterofracture floret disjunction are not included, the results are as follows:

Floret disjunction by—	Spikelet disarticulation by—		
	Abscission	Semiabscission	Fracture
	Per cent	*Per cent*	*Per cent*
Basifracture	39.9	30.4	29.7
Disarticulation	12.4	18.5	69.1

Apparently the correlation between floret disjunction by disarticulation and spikelet disarticulation by fracture as a rule is more pronounced than that between floret disjunction by basifracture and spikelet disarticulation by abscission. The coefficient of association (Q) in this case was determined by adding the number of kernels in which floret disjunction was by heterofracture to that by basifracture and by adding those in which spikelet disarticulation was from abscission and semiabscission respectively. Arranged in this way, the data are as follows:

Floret disjunction by—	Spikelet disarticulation by—	
	Abscission and semiabscission	Fracture
Basifracture, Heterofracture	2,179	956
Disarticulation	2,764	6,183

$Q=0.672\pm0.003$

These data indicate that a high degree of association exists ($Q=0.672\pm0.003$) between certain phases of spikelet disarticulation and certain phases of floret disjunction. Spikelet disarticulation resulting from abscission and semiabscission apparently is closely associated with floret disjunction by basifracture and heterofracture, while spikelet disarticulation by fracture is associated with floret disjunction by disarticulation. In other words, the two *byzantina* characters are associated as also are the two *sativa* characters.

SPIKELET DISARTICULATION AND BASAL HAIRS

The data on correlation between spikelet disarticulation and basal hairs are presnted in Table XII. It is evident that correlation exists between spikelet disarticulation by fracture (without a basal cavity) and the absence of basal hairs. Correlation exists between the basal cavity (resulting from abscission) and the presence of basal hairs, but this correlation does not seem to be as marked as the former one. In determining the value of Q for these characters, the kernels disarticulating by semiabscission were added to those disarticulating by abscission and the abundant long, abundant midlength, and few classes of basal hairs were all combined into one class and considered as basal hairs present, the data being arranged as follows:

Spikelet disarticulation by—	Basal hairs	
	Present	Absent
Abscission, Semiabscission	4,354	589
Fracture	1,855	5,284

$Q=0.909\pm0.001$

TABLE XII.—*Data on association of spikelet disarticulation and basal hairs in 9 strains of Burt oat grown at the Kansas Agricultural Experiment Station in 1920*

Strain number and kind of spikelet disarticulation in kernels	Basal hairs							
	Number of kernels having hairs—				Percentage of kernels having hairs—			
	Abundant		Few	Absent	Abundant		Few	Absent
	Long	Mid-length			Long	Mid-length		
Kansas No. 5020:								
Abscission	0	111	95	3	0	53.1	45.5	1.4
Semiabscission	0	18	336	42	0	4.5	84.9	10.6
Fracture	0	0	282	756	0	0	27.2	72.8
Kansas No. 5211:								
Abscission	60	247	481	11	7.5	30.9	60.2	1.4
Semiabscission	0	25	361	46	0	5.8	83.6	10.6
Fracture	0	0	154	674	0	0	18.6	81.4
Kansas No. 5219:								
Abscission	27	122	537	51	3.6	16.6	72.9	6.9
Semiabscission	2	78	612	76	.3	10.1	79.7	9.9
Fracture	0	0	63	336	0	0	15.8	84.2
Kansas No. 5220:								
Abscission	0	18	80	3	0	17.8	79.2	3.0
Semiabscission	0	14	93	62	0	8.3	55.0	36.7
Fracture	0	0	153	456	0	0	25.1	74.9
Kansas No. 6004:								
Semiabscission	0	0	17	1	0	0	94.4	5.6
Fracture	0	0	348	571	0	0	37.9	62.1
Kansas No. 6052:								
Semiabscission	0	0	16	5	0	0	76.2	23.8
Fracture	0	0	286	1,114	0	0	20.4	79.6
Kansas No. 6076:								
Semiabscission	0	0	39	51	0	0	43.3	56.7
Fracture	0	0	370	535	0	0	40.9	59.1
Kansas No. 6090:								
Abscission	0	108	219	20	0	31.1	63.1	5.8
Semiabscission	0	23	252	132	0	5.7	61.9	32.4
Fracture	0	0	94	513	0	0	15.5	84.5
Kansas No. 6094:								
Abscission	0	117	60	1	0	65.7	33.7	0.6
Semiabscission	0	2	184	85	0	.7	67.9	31.4
Fracture	0	3	102	329	0	.7	23.5	75.8
All strains:								
Abscission	87	723	1,472	89	3.7	30.5	62.1	3.7
Semiabscission	2	160	1,910	500	.1	6.2	74.3	19.4
Fracture	0	3	1,852	5,284	0	.1	25.9	74.0

$Q = 0.909 \pm 0.001$

The data presented in Table XII for each of the nine strains show that the correlation existing between spikelet disarticulation by abscission and abundant midlength basal hairs varies in the different strains. In Kansas Nos. 5020 and 6094, 53.1 and 65.7 per cent, respectively, of the kernels having this disjunction method also had abundant midlength basal hairs. In the other four strains in which kernels having this disjunction method were observed there also was correlation between these two characters but it was not so high.

Kernels in which spikelet disjunction was by semiabscission generally were found to have few basal hairs. The correlation between these two characters varied slightly in different strains but was very pronounced in every strain grown. In only one strain, Kansas No. 6076, did less than 50 per cent of the kernels disarticulating by semiabscission have few basal hairs. These correlations might be taken as clearly indicating the heterozygous condition of the kernels in either of these classes.

The data for the different strains show conclusively that there is correlation between spikelet disarticulation by fracture and the absence of basal hairs. In seven of the nine strains more than 70 per cent of the kernels disarticulating by fracture had no basal hairs. In some strains these two conditions were associated in more than 80 per cent of the kernels.

Only 3.7 per cent of the kernels disarticulating by abscission were without basal hairs. Less than 0.1 per cent

of the kernels disarticulating by fracture had abundant midlength basal hairs, while 74 per cent of them were without basal hairs. As might be expected, it is very unusual for kernels of Burt oat to have abundant midlength basal hairs in the absence of the basal cavity.

A very high degree of association is evident between spikelet disarticulation by abscission (presence of basal cavity) and presence of basal hairs ($Q=0.909\pm0.001$). Abundant basal hairs occur most frequently on kernels having the prominent basal cavity which is characteristic of varieties of *Avena byzantina*.

SPIKELET DISARTICULATION AND AWNS

The summarized data on the correlation between spikelet disarticulation and awns for all strains are presented in Table XIII. As in the cases previously considered, in determining the value of Q, the semiabscission and abscission spikelet disjunction classes were combined. The twisted and the nontwisted long and short classes of awns also were all combined in the class "awns present," which was contrasted with the "awns absent" class, according to the following scheme:

Spikelet disarticulation by—	Awns	
	Present	Absent
Abscission, Semiabscission	4,570	373
Fracture	2,371	4,768

$Q=0.922\pm0.0009$

It is evident that high correlation exists between spikelet disarticulation by abscission and semiabscission (presence of a basal cavity) and the presence of awns. It is evident also that correlation exists between the absence of awns and spikelet disarticulation by fracture (absence of a basal cavity). These conditions are associated in about 67 per cent of the cases. There was a much higher percentage of fracturing kernels which bore long awns than of those disarticulating by abscission which lacked awns.

TABLE XIII.—*Data on association of spikelet disarticulation and awns in 9 strains of Burt oat grown at the Kansas Agricultural Experiment Station in 1920*

Strain number and kind of spikelet disarticulation in kernels	Number of kernels with awns—				Percentage of kernels with awns—			
	Twisted	Nontwisted		Absent	Twisted	Nontwisted		Absent
		Long	Short			Long	Short	
Kansas No. 5020:								
Abscission	0	127	81	1	0	60.8	38.7	0.5
Semiabscission	13	193	127	63	3.3	48.7	32.1	15.9
Fracture	55	259	120	604	5.3	24.9	11.6	58.2
Kansas No. 5211:								
Abscission	1	543	246	9	.1	68.0	30.8	1.1
Semiabscission	35	164	159	74	8.1	38.0	36.8	17.1
Fracture	187	218	77	346	22.6	26.3	9.3	41.8
Kansas No. 5219:								
Abscission	0	500	221	7	0	69.1	30.0	.9
Semiabscission	23	457	249	39	3.0	59.5	32.4	5.1
Fracture	71	73	29	226	17.8	18.3	7.3	56.6
Kansas No. 5220:								
Abscission	5	48	46	2	5.0	47.5	45.5	2.0
Semiabscission	31	61	34	43	18.3	36.1	20.1	25.5
Fracture	62	100	101	337	10.2	17.9	16.6	55.3
Kansas No. 6004:								
Semiabscission	1	13	2	2	5.6	72.2	11.1	11.1
Fracture	66	58	10	785	7.2	6.3	1.1	85.4
Kansas No. 6052:								
Semiabscission	7	9	3	2	33.3	42.9	14.3	9.5
Fracture	181	214	70	935	12.9	15.3	5.0	66.8
Kansas No. 6076:								
Semiabscission	19	29	16	26	21.1	32.2	17.8	28.9
Fracture	7	55	20	823	.8	6.1	2.2	90.9
Kansas No. 6090:								
Abscission	0	209	129	9	0	60.2	37.2	2.6
Semiabscission	0	173	173	61	0	42.5	42.5	15.0
Fracture	24	44	33	506	4.0	7.2	5.4	83.4
Kansas No. 6094:								
Abscission	0	124	54	0	0	69.7	30.3	0
Semiabscission	131	75	30	35	48.3	27.7	11.1	12.9
Fracture	173	35	20	206	39.8	8.1	4.6	47.5
All strains:								
Abscission	6	1,560	777	28	.2	65.8	32.8	1.2
Semiabscission	260	1,174	793	345	10.1	45.7	30.8	13.4
Fracture	826	1,065	480	4,768	11.6	14.9	6.7	66.8

$Q=0.922\pm0.009$

From the data presented in Table XIII it does not appear that spikelet disarticulation by semiabscission is strongly correlated with any one kind of awn, although more often kernels disarticulating by semiabscission have nontwisted long or short awns than twisted awns or awns absent. In every strain there is a marked tendency for the nontwisted long awns and disarticulation by abscission to be associated, while a comparatively high percentage of the kernels disarticulating by fracture had awns absent. The twisted awn does not appear to be associated with any spikelet disarticulation method, although there seems to be some evidence of lack of association between the twisted awn and abscission. This, together with the data on inheritance of awns in other portions of this paper, indicates that the twisted awn is possibly genetically distinct from the other awn types in the strains of Burt oat used in these experiments.

TABLE XIV.—*Data on association of lemma color and spikelet disarticulation in 9 strains of Burt oat grown at the Kansas Agricultural Experiment Station in 1920*

Strain number and lemma color in kernels	Spikelet disarticulation					
	Number of kernels disarticulating by—			Percentage of kernels disarticulating by—		
	Abscission	Semiabscission	Fracture	Abscission	Semiabscission	Fracture
Kansas No. 5020:						
Black	0	24	3	0	88.9	11.1
Brown	162	327	505	16.3	32.9	50.8
Red	38	45	461	7.0	8.3	84.7
Yellow	9	0	63	12.5	0	87.5
White	0	0	6	0	0	100.0
Kansas No. 5211:						
Black	17	4	29	34.0	8.0	58.0
Brown	418	178	358	43.8	18.7	37.5
Red	362	237	315	39.6	25.9	34.5
Yellow	2	13	126	1.4	9.2	89.4
Kansas No. 5219:						
Black	4	32	4	10.0	80.0	10.0
Brown	444	552	254	35.5	44.2	20.3
Red	239	171	141	43.4	31.0	25.6
Yellow	50	13	0	79.4	20.6	0
Kansas No. 5220:						
Black	0	7	6	0	53.8	46.2
Brown	18	101	200	5.6	31.7	62.7
Red	83	48	280	20.2	11.7	68.1
Yellow	0	13	118	0	9.9	90.1
White	0	0	5	0	0	100.0
Kansas No. 6004:						
Brown	0	17	231	0	6.9	93.1
Red	0	1	582	0	.2	99.8
Yellow	0	0	106	0	0	100.0
Kansas No. 6052:						
Brown	0	19	369	0	4.9	95.1
Red	0	2	603	0	0.3	99.7
Yellow	0	0	412	0	0	100.0
White	0	0	16	0	0	100.0
Kansas No. 6076:						
Black	0	0	11	0	0	100.0
Brown	0	52	141	0	26.9	73.1
Red	0	27	286	0	8.6	91.4
Yellow	0	11	467	0	2.3	97.7
Kansas No. 6090:						
Black	16	13	6	45.7	37.1	17.2
Brown	299	355	533	25.2	29.9	44.9
Red	32	39	57	25.0	30.5	44.5
Yellow	0	0	11	0	0	100.0
Kansas No. 6094:						
Black	2	0	0	100.0	0	0
Brown	58	139	142	17.1	41.0	41.9
Red	89	92	144	27.4	28.3	44.3
Yellow	29	40	143	13.7	18.9	67.4
White	0	0	5	0	0	100.0
All strains:						
Black	39	80	59	21.0	47.3	31.7
Brown	1,399	1,740	2,733	23.8	29.6	46.6
Red	843	662	2,869	19.3	15.1	65.6
Yellow	90	90	1,446	5.5	5.5	89.0
White	0	0	32	0	0	100.0

$Q=0.501\pm0.005$.

LEMMA COLOR AND SPIKELET DISARTICULATION

The summarized data on correlation between spikelet disarticulation and lemma color, as presented in Table XIV, indicate that some correlation exists between these characters. The coefficient of association was determined in this case by combining the black and brown color classes as dark and the red, yellow, and white as light. Two disarticulation classes were combined as before, that is, abscission and semiabscission were added together in contrast to the fracture class. The data thus arranged appear as follows:

Lemma color	Disarticulation	
	Abscission and semiabscission	Fracture
Dark	3,258	2,792
Light	1,685	4,347

$Q=0.501 \pm 0.005$

The data indicate that most of the kernels, without respect to color, disarticulated by fracture. As a rule in those strains in which a high percentage of kernels of one color disarticulated by abscission, high percentages of the kernels of all colors disarticulated in the same manner.

There is association between lemma color and spikelet disarticulation or basal form. Dark kernels most often have the prominent basal cavity resulting from disarticulation by abscission, while yellow or white kernels seldom are found in strains disarticulating in this way.

The data indicate that generally the yellow and white kernels disarticulate by fracture. This agrees with the observations of Love and Craig (*71*) and others. The darker-colored kernels are found associated more often with the spikelet disarticulation by abscission while light-colored kernels are more often associated with spikelet disarticulation by fracture. The association between dark color and abscission apparently is not as strong as that between light color and fracture.

LEMMA COLOR AND AWNS

The data on the correlation between lemma color and awns are presented in Table XV. As in the cases previously described, the classes for lemma color and awns were grouped so as to make only two classes of each, as follows:

Lemma color	Awns	
	Present	Absent
Dark	4,104	1,946
Light	2,837	3,195

$Q=0.407 \pm 0.005$

The results obtained in this study indicate that the twisted awn must be different in genetic constitution from the other classes of awns. In the study of correlation between awns and lemma color it is found that practically the same percentages of twisted awns appeared in each color class with the exception of white.

If the data for the long and short nontwisted awns are combined as nontwisted, the following figures are obtained:

Lemma color	Character of awn		
	Twisted	Nontwisted	Absent
	Per cent	*Per cent*	*Per cent*
Black	7.9	64.6	27.5
Brown	9.4	58.3	32.3
Red	8.0	44.8	47.2
Yellow	10.8	21.4	67.8
White	0	6.2	93.8

The figures indicate a consistent and significant decrease in the nontwisted awn class in passing from the darker to the lighter colors.

The data for each of the strains are in general agreement with the conclusions drawn from the summary data, although in some strains the relation between lemma color and awns is less definite than in others.

The presence or absence of awns may be rather uniformly either low or high for all colors in a given strain. The variations or irregularities which occur in these strains probably may be accounted for by the fact that only a few individuals were studied.

In general, it may be stated that some correlation exists between color of lemma and the type of awn in the Burt oat used in these experiments. The lighter-colored kernels as a rule have fewer nontwisted awns than the darker kernels.

The three awn classes—twisted, nontwisted, and absent—are clearly different in breeding behavior as indicated in the studies of independent inheritance and as shown by their associations with other spikelet characters.

TABLE XV.—*Data on association of lemma color and awn class in 9 strains of Burt oat grown at the Kansas Agricultural Experiment Station in 1920*

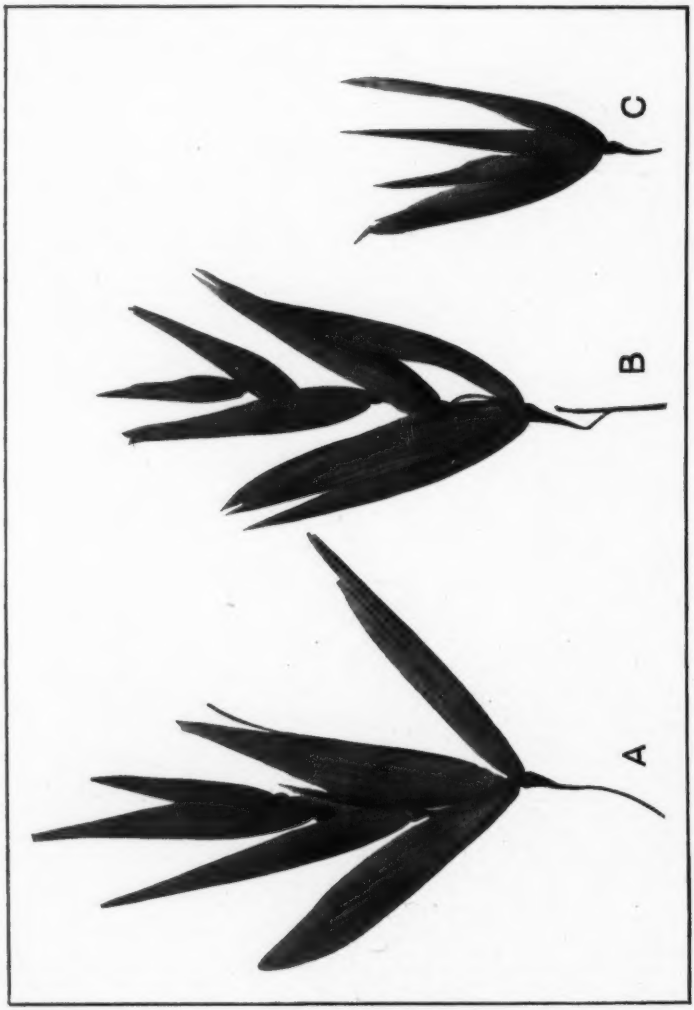
Strain number and lemma color in kernels	Awn classes in progeny							
	Number of kernels with awns—				Percentage of kernels with awns—			
	Twisted	Nontwisted		Absent	Twisted	Nontwisted		Absent
		Long	Short			Long	Short	
Kansas No. 5020:								
Black	0	7	5	15	0	25.9	18.5	55.6
Brown	63	396	228	307	6.4	39.8	22.9	30.9
Red	5	155	85	299	.9	28.5	15.6	55.0
Yellow	0	20	9	43	0	27.8	12.5	59.7
White	0	1	1	4	0	16.7	16.7	66.6
Kansas No. 5211:								
Black	11	26	9	4	22.0	52.0	18.0	8.0
Brown	138	466	180	170	14.5	48.8	18.9	17.8
Red	58	361	280	215	6.4	39.5	30.6	23.5
Yellow	16	72	13	40	11.3	51.1	9.2	28.4
Kansas No. 5219:								
Black	0	20	13	7	0	50.0	32.5	17.5
Brown	83	656	322	189	6.6	52.5	25.8	15.1
Red	11	316	148	76	2.0	57.3	26.9	13.8
Yellow	0	47	16	0	0	74.6	25.4	0
Kansas No. 5220:								
Black	3	2	2	6	23.1	15.4	15.4	46.1
Brown	62	92	53	112	19.5	28.8	16.6	35.1
Red	33	105	108	165	8.0	25.5	26.3	40.2
Yellow	0	19	18	94	0	14.5	13.7	71.8
White	0	0	0	5	0	0	0	100.0
Kansas No. 6004:								
Brown	55	51	12	130	22.2	20.6	4.8	52.4
Red	11	15	0	557	1.9	2.6	0	95.5
Yellow	1	5	0	100	1.0	4.7	0	94.3
Kansas No. 6052:								
Brown	44	74	13	257	11.3	19.1	3.4	66.2
Red	71	111	46	377	11.7	18.4	7.6	62.3
Yellow	73	38	14	287	17.7	9.2	3.4	69.7
White	0	0	0	16	0	0	0	100.0
Kansas No. 6076:								
Black	0	5	4	2	0	45.4	36.4	18.2
Brown	0	56	21	116	0	29.0	10.9	60.1
Red	25	13	7	268	8.0	4.2	2.2	85.6
Yellow	1	10	4	463	.2	2.1	.8	96.9
Kansas No. 6090:								
Black	0	16	4	15	0	45.7	11.4	42.9
Brown	8	367	287	525	.7	30.9	24.2	44.2
Red	12	43	44	29	9.4	33.6	34.4	22.6
Yellow	4	0	0	7	36.4	0	0	63.6
Kansas No. 6094:								
Black	0	2	0	0	0	100.0	0	0
Brown	98	93	57	91	28.9	27.4	16.8	26.9
Red	126	92	32	75	38.8	28.3	9.8	23.1
Yellow	80	47	15	70	37.7	22.2	7.1	33.0
White	0	0	0	5	0	0	0	100.0
All strains:								
Black	14	78	37	49	7.9	43.8	20.8	27.5
Brown	551	2,251	1,173	1,897	9.4	38.3	20.0	32.3
Red	352	1,211	750	2,061	8.0	27.7	17.1	47.2
Yellow	175	258	89	1,104	10.7	15.9	5.5	67.9
White	0	1	1	30	0	3.1	3.1	93.8

$Q = 0.407 \pm 0.005$

There is some degree of association between lemma color and nontwisted awns ($Q = 0.407 \pm 0.005$). Little if any association is apparent between the twisted awn and lemma color. This furnishes additional evidence of the fact that this awn probably belongs to a genotype very distinct from the other awn types. The light-colored kernels are more frequently awnless than are the dark-colored kernels. Nontwisted long awns are found much more numerous in the dark-colored kernel classes.

PLANT VARIANTS

These experiments have been chiefly concerned with the study of kernel characters. However, several interesting variations in plant characters have been observed. Different pedigreed lines vary considerably in the growth habit of the young plants. Some are as prostrate as plants of Red Rustproof or Winter Turf, others are semierect, somewhat resembling Fulghum, while the majority of plants have the erect



(For explanatory legend see p. 57)

habit characteristic of such varieties as Kherson and Swedish Select. Variations in size of culm, leaf width, leaf color, and other plant characters also have been observed, as well as distinct differences in time of heading and of ripening. A few plants were observed among the material grown at Akron Field Station in 1921, which appeared to have the growth habit of true winter oats and which failed to produce heading culms.

A few of the more unusual plant variations will be described in a little greater detail because of their relation to the general problem of variability in Burt oat. It is expected that the breeding behavior of some of these variants will be more fully described in other papers. It is interesting to note that while more plant variations have been observed in Burt than in almost any other variety, no dwarf forms such as have been described by Warburton (*145*) and Stanton (*125*) have yet been observed in Burt. It also is noteworthy that only a few false wild types have been observed in these experiments on variability in Burt oat, although they frequently occur in some other varieties of *Avena byzantina*.

CHLOROPHYLL DEFICIENCY

The first of these variations observed exhibited a chlorotic condition, manifested in the form of leaf striping. Chlorophyll abnormalities in small grains have been described by Nilsson-Ehle (*94, 97*), Kalt (*56*), Kiessling (*59, 60*), Akerman (*3*), Christie (*19*), Wiebe,[22] and others. East and Hayes (*31*), Emerson (*32*), Gernert (*46*), Miles (*78*), and Lindstrom (*65, 66*) have described various chlorotic types in corn.

The original showing this striped condition of the leaves was first noticed in 1920 at the Akron Field Station shortly after the plant emerged, and throughout the life of the plant, as far as could be observed, the proportionate area of the leaves affected remained the same, neither increasing nor decreasing as the plant developed. This plant made only about one-half the growth attained by the normal green plants from the same parental strain and matured a single panicle bearing a few kernels.

Seeds of this plant were sown in 1921 at the Akron station, but out of 13 seedlings only 1 plant reached maturity. Some of these plants appeared to be white, or entirely devoid of chlorophyll. The 1 plant grown to maturity in 1921 showed the striped condition similar to the original variant, but the striping was less marked. The seeds of this plant were sown in individual pots in the greenhouse of the Kansas Agricultural Experiment Station at Manhattan in the fall of 1921. The chlorotic condition was exhibited in varying degrees by a considerable number of the plants grown. No albinos appeared among these progeny plants.

Seed from each of the plants grown to maturity in the greenhouse at Manhattan in the winter of 1921–22 was sown at the Akron station in 1922. About 800 plants were grown, of which a considerable percentage exhibited the chlorotic condition in varying degrees, ranging from only a few rather indistinct longitudinal yellowish-white stripes to the apparent total absence of chlorophyll.

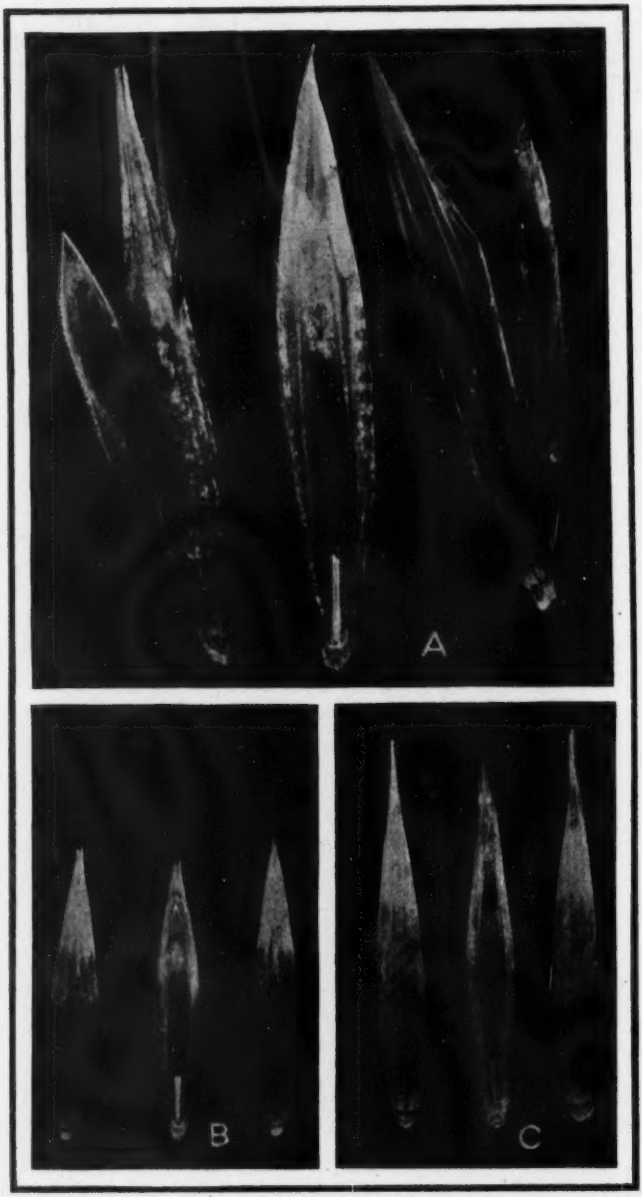
MULTIFLOROUS SPIKELETS

A second variant type was observed in 1920 at Akron. It had the multiflorous spikelets which Stanton (*124*) has shown to characterize the hull-less or naked oat. This variation has been described by Coffman and Quisenberry (*20*). The outer glumes were long, resembling those of *Avena nuda*. The spikelets were multiflorous, containing from two to six florets per spikelet which Spillman (*122*) has reported that Von Tschermak found to be correlated with the hull-less condition of *A. nuda*. Approximately 40 to 50 per cent of the kernels threshed free from the glumes as in *Avena nuda*. The plant was similar in general appearance to the F_1 plant of a cross between a hulled and a hull-less oat, as described by Norton (*99*), Zinn and Surface (*161*), Gaines (*40*), Caporn (*14*), and Love and McRostie (*73*). All of these writers have observed that the F_1 plants of the hulled × hull-less cross exhibit an intermediate condition and that hulled and hull-less kernels are found in the F_1 plants in varying percentages. Caporn (*14*) has observed a definite arrangement of hulled and hull-less kernels in the various parts of the panicles of the F_1 plants. No such arrangement was observed in this variant plant nor in the progeny grown from it.

[22] WIEBE, G. A. A CASE OF ALBINISM IN BARLEY. Jour. Heredity. 15:221–222. 1924

EXPLANATORY LEGEND FOR PLATE 7

A.—Multiflorous spikelet of Burt oat, Kansas No. 6090, resembling *Avena nuda*. Note the dark color and firm texture of lemmas of upper florets. B.—Typical multiflorous spikelet of hull-less oat, *Avena nuda*. C.—Typical spikelet of Burt oat, Kansas No. 6090.



A.—Loose palea from Kansas No. 6076 approaching the condition found in the hull-less oat. B.—Short and very broad kernels from Kansas No. 6052. C.—Long and broad kernels from Kansas No. 5220.

Plants of this variant type were grown at the Akron and Manhattan stations in 1921 and at the Akron Field Station and the West Virginia Agricultural Experiment Station in 1922. These experiments have shown that this multiflorous condition is heritable, though there is considerable variation in the progenies with respect to the percentage of kernels remaining inclosed in the lemmas after threshing. A spikelet of this variation is shown in Plate 7, in comparison with those of normal Burt oat and *Avena nuda*, the hull-less oat.

LOOSE PALEAS

Several plants were observed among the 1920 progeny at both the Akron and Manhattan stations in which the paleas of the kernels did not closely inclose the caryopsis. In some of these the palea was curled away from the lemma, leaving the caryopsis exposed. Such kernels were seeded in 1921 at both stations and the plants grown proved the condition to be heritable to some extent. Plate 8 shows several of these kernels.

FALSE WILD OAT

Criddle (*24*) observed false wild forms in the Early Ripe oat, a variety very similar to Burt. These false wild forms have been discussed by Fischer (*35*), Norton (*98*), Criddle (*24, 25*), Nilsson-Ehle (*93, 96*), Newman (*86, 87*), Zade (*153, 154*), Atwood (*6*), Von Tschermak (*137*), Pridham (*106*), Robb (*113*), Agar (*1*), Gante (*41*), Hayes and Garber (*47*), Crepin (*23*), Akerman (*2*), Garber (*42*), and Garber and Quisenberry (*43*). A few plants bearing kernels resembling the false wild forms described in publications named above were first observed in the material grown at Akron in 1920. More recently a number of such aberrant individuals were found in Burt at Akron, and one was selected from a strain of this variety by W. H. von Trebra at the Colby (Kansas) Substation in 1924. In these forms the basal cavity was very prominent on the upper as well as the lower kernels of the spikelets. Both the primary and secondary kernels bore awns which were markedly twisted. Abundant hairs practically surrounded the base of the lemma and were present on the rachillas of both kernels. The presence of a few hairs also was observed on the dorsal surface of some kernels. The false wild kernels were of a yellowish-red color. Kernels of false wild oats which occurred in selection No. 16–3 of Kansas strain No. 6076 of Burt grown at Akron in 1920 are illustrated in Plate 9.

SUMMARY

A review of the literature on classification and breeding experiments with oats is presented, with special reference to the characters considered in this paper.

Experiments of different investigators have shown that certain strains of Burt oat are resistant to crown rust and to smut. These characters add to the value of the variety.

The Burt oat has considerable economic value due to its wide adaptability, early maturity, drought resistance, and resistance to smut and crown rust.

The commercial Burt oat is composed of a large number of distinct strains and many of these are heterozygous. This variety has been classified as *Avena sativa* by Carleton (*17*), *Avena sterilis* by Etheridge (*33*), and in other ways by other investigators. There seems to be little basis for the suggestion of Waller (*141*) that the Burt oat belongs to *Avena barbata*.

Burt may belong to a distinct group, as suggested by Norton (*98*), but the writers consider it as belonging to *Avena byzantina*, the species accepted by many European taxonomists as including cultivated descendants of *Avena sterilis*. This species is recognized as being variable in its breeding behavior and as containing strains which resemble those of *Avena sativa*.

Investigators do not agree concerning the amount of natural crossing which takes place in oats. The writers believe that field crosses may occur rather frequently, the amount of natural crossing varying with the variety and environmental conditions.

Spikelet disarticulation in the Burt oat appears to breed as a simple monohybrid. The roughened type of base resulting from fracture, very similar to that of *Avena sativa*, apparently is dominant. The base resulting from abscission and containing a prominent cavity apparently is recessive.

Two types of floret disjunction are found in Burt oat, the *sativa* or disarticulating form predominating. The *byzantina* or basifracture form, in its breeding behavior, somewhat suggests a cross involving multiple factors.

The development of basal hairs in Burt is a character which appears to be complex in breeding behavior. Probably several factors are concerned. The abundant long hairs appear to be recessive.

Several factors probably determine the breeding behavior of awns in the Burt oat. The twisted awn bred more nearly true than did any of the others.

This type of awn behaves as a recessive character and apparently is distinct genetically from the other types of awn.

The results obtained on the inheritance of lemma color in the Burt oat indicate that red is the most stable in breeding behavior. The dark browns and blacks tend to produce a high percentage of dark kernels and seem to have a similar genetic constitution. Some of the kernels of the 1920 crop described as light brown and yellow probably were genetic reds manifesting the effects of physiological influences. Other workers have shown that white is a recessive kernel color in oats. In the experiments of the writers, however, the parental kernels classed as white did not produce a high percentage of white progeny kernels. This may have been due to weathering, immaturity, and physiological influences which prevented the development of, or which obscured, the true color.

In the study of association between spikelet characters in Burt oat it has been found that correlation exists among the following characters: (1) Floret disjunction and spikelet disarticulation; (2) spikelet disarticulation and basal hairs; (3) spikelet disarticulation and awns; (4) lemma color and spikelet disarticulation; (5) lemma color and awns.

Burt oat has been shown to vary in many observable plant characters, such as habit of growth of the young plant, leaf color and leaf width, time of heading and ripening, and others. Several distinct variants have been observed, among them one showing a chlorotic condition of the leaves, one having multiflorous spikelets, one with loose paleas, and the false wild forms.

These experiments provide a basis for future breeding experiments with Burt oat. The possibility of isolating comparatively pure-breeding strains from the variety is pointed out. The use of strains of Burt oats as parental material in genetic experiments without first carefully observing their breeding behavior for several years in pedigree culture is shown to be not in accord with accepted genetic methods.

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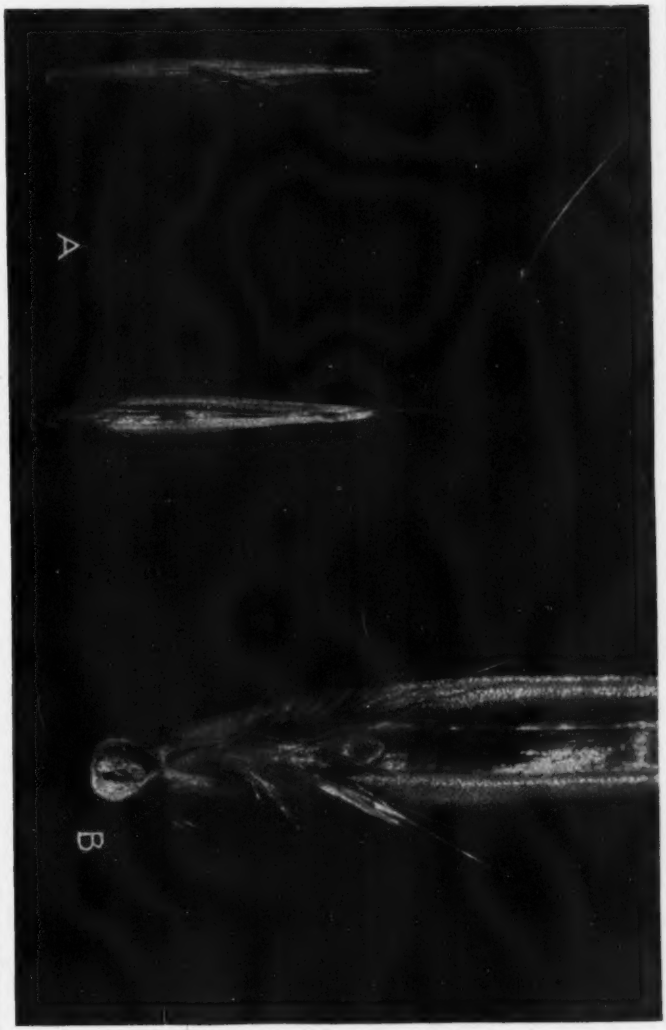
EXPLANATORY LEGEND FOR PLATE 9

A.—Dorsal and ventral views of kernels of the so-called "false wild" oat showing long and twisted geniculate awns. B.—Enlargement of basal portion of one kernel of the so-called "false wild" showing characters common to wild oat species, namely, disarticulation by abscission, (1) with resulting basal cavity with smooth margins; (2) floret disjunction by disarticulation, leaving the second rachilla segment attached ventrally to the lower floret, and (3) abundant long hairs on the rachilla segment



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THE COMPOSITE LIFE HISTORY OF PUCCINIA PODOPHYLLI SCHW.[1]

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The common rust, *Puccinia podophylli* Schw., presents certain features which make it of special interest to the student of the biology of this great group of plant parasites. The interest in this species lies primarily in the peculiar sequence in the seasonal appearance of the spore forms. This species is an opsis-form, possessing aecia and telia only, and occurs on the common mandrake or May-apple, *Podophyllum peltatum* L., practically throughout its range.

Puccinia podophylli produces teliospores at two different periods during the season; the first crop appears early in the spring on the sheath leaves or bud scales, on the stem usually at the base and sometimes on the sepals (Pl. 1, A and B); the second crop appears later in the summer on the under side of the fully expanded and matured leaves (Pl. 4, B). Between these two crops of teliospores the aecia, usually preceded by pycnia, are developed on the expanding leaves (Pl. 2). It is also of interest that telia often develop in association with the aecial clusters on the leaves and to all appearances on the same mycelium before the appearance of the second crop of teliospores, which obviously develop from aecial infection (Pls. 2, 3, and 4, A). The explanation of the origin of these early telial sori and the determination of the life history of this species are the objects of the study reported in this paper.

HISTORY

The only previous attempt to explain the life history of this species and the sequence of the spore forms was made by Olive (*6*). Based primarily on cytological evidence, he reached the conclusion that the first crop of telia and the pycnia and aecia arise from an intermingled growth of the mycelium of the gametophytic and sporophytic generations which are independently and simultaneously perennial in the host plant. He conducted no culture work nor did he attempt to verify this assumption by an histological study of the root stalk or overwintering buds.

The following summary of Olive's work is presented in some detail, largely by quotation, in order to bring out clearly his cytological observations and the conclusions he drew from them since it will be necessary to refer to these details later in this paper.

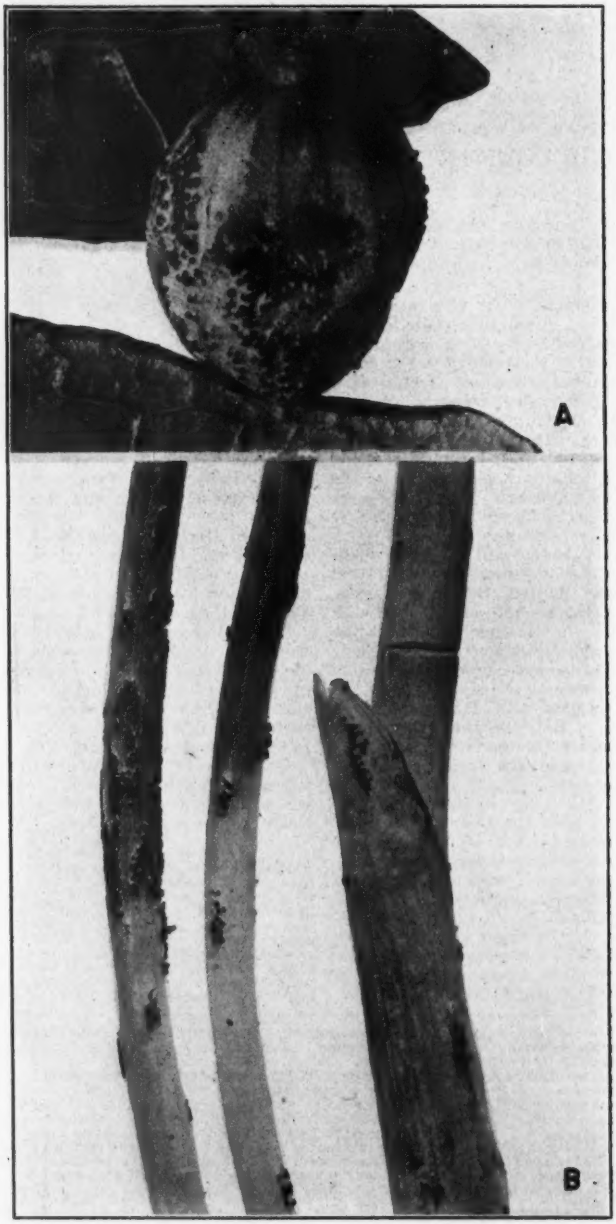
Olive found that the mycelium in the lesions on the sheath leaves that bore the early telia was prevailingly binucleate, as one would expect.

> The preparations also show, occasionally, a few aecidium cups on these same sheaths * * *. I have not yet found spermogonia on the sections of these young sheaths; but their occasional occurrence in such situations may be expected from the fact that a small amount of uninucleate mycelium occurs, especially in the region surrounding the aecidial sori, there forming the meager pseudo-parenchyma. But the rust mycelium of the sheath, in contradistinction to that in the young leaves, is undoubtedly prevailingly binucleate. Further, I

[1] Received for publication May 24, 1924—issued April, 1925. Joint contribution from the Department of Botany, Purdue University Agricultural Experiment Station and the Department of Plant Pathology, Cornell University.

[2] A report on the experiment conducted at Ithaca, N. Y., together with an interpretation of the life history essentially the same as that given in this paper, was presented before the Botanical Society of America at the Pittsburgh meeting of the American Association for the Advancement of Science in 1917 by Prof. H. H. Whetzel (not published). The problem had been freely discussed with me during the two previous years and my interest aroused. It was mutually agreed that a more detailed cultural study would be desirable and this work was begun at LaFayette, Ind., in 1917, having been planned in collaboration with my associate, Dr. E. B. Mains, who carried out the details of the cultures. It was finally decided to present the combined results in a joint paper, the preparation of which has been my responsibility.—H. S. Jackson.

[3] Reference is made by number (italic) to "Literature cited."



A.—Telia of *Puccinia podophylli* on the sepals. Note the aeciallike character of these telia. Natural infection slightly enlarged
B.—Telia on bud scales and on the stem. Natural infection. Compare with Plate 4, B. Natural size.

am convinced that the aecidia which are borne on the sheaths arise, not from gametophytic cell fusions, but only from preëxisting binucleate hyphae; therefore being secondary and sporophytic in character, and thus similar in origin to the teleutospores.

He found in the lesions on the leaves that a much more abundant uninucleate mycelium is present in the younger tissues and that the pycnia arise from this mycelium.

In those older leaves, however, in which the aecidia have begun to form their chains of spores, binucleate mycelium has become quite prevalent in all the sections examined, especially at the bases of the aecidial cups. These sporophytic hyphae intermingle with the uninucleate mycelium, often entering the broad, caeoma like base of the young aecidium, there functioning directly as basal cells of the rows of the binucleate aecidiospores. In still older stages on leaves, binucleate mycelium apparently prevails by the time the aecidium cups have for the most part broken open to discharge their spores, * * *.

His examination of the later telia which form from aeciospore infection shows that they arise from a localized binucleate mycelium.

In interpreting the results of his observations he assumes that the uninucleate, or gametophytic mycelium, and the binucleate or sporophytic mycelium, are independently but simultaneously perennial in the plants from which his material was taken and that the pycnia are the only structure borne on the uninucleate mycelium, while both the early teliospores and the aecia develop from the binucleate mycelium. He assumes that basidiospore infection would result in a localized mycelium on which pycnia and aecia would be developed, the expectation being that this would be prevailingly uninucleate.

In connection with a discussion of the principle that in perennial rusts the gametophytic mycelium in young shoots grows more vigorously early in the season than the sporophytic, the following quotation is of interest:

The fact that the teleutosori break out very early from the tissues of the leaf sheaths, some distance below the tip of the stem, and that the binucleate mycelium prevails in these sheaths almost to the exclusion of the uninucleate hyphae does not, to my mind, vitiate the above statement, which applies only to the younger tissues of the shoot. I interpret these facts somewhat as follows: the uninucleate mycelium grows with especial vigor into the rapidly expanding tip and young leaves of the new shoot, growing somewhat ahead of the lagging sporophyte. The latter apparently chooses ordinarily the more mature tissues for its most vigorous growth and thus early comes to predominate in the riper tissues of the poorly nourished leaf sheaths of Podophyllum, as well as later in the older leaf tissues.

As a part of Olive's discussion of the probable reason for the development of the early telia on the sheaths and later the secondary aecia on the leaves from the same binucleate mycelium, the following significant statements are found:

Quite likely the degree of maturity of the tissues and the quality of the nourishment supplied to the parasite govern largely this phenomenon of the early development of the teleutospores, just as these factors doubtless determine the cessation of the production of the repeating spores and the beginning of the production of the teleutospores in other long-cycled rusts. The tissues making up the leaf sheaths of young shoots of Podophyllum are undoubtedly mature, as well perhaps as poorly nourished, as is shown by the character of the contained protoplasm; hence they present conditions at a very early stage not met with again until the host gains maturity or even old age.

It is obviously quite impossible to suppose that this early teleutosporic stage in *Puccinia podophylli* has arisen in any other way than from hibernating sporophytic mycelium, which has grown up with the infected buds in the spring. It could not come from an early infection since the aecidiospores, which we assume to be the only spores from the inoculation of which the teleutospores could arise, have not yet begun to form. I will have to confess, however, that I have not been able to apply de Bary's test to this species and to look for hibernating mycelium in the underground parts.

CULTURE EXPERIMENTS

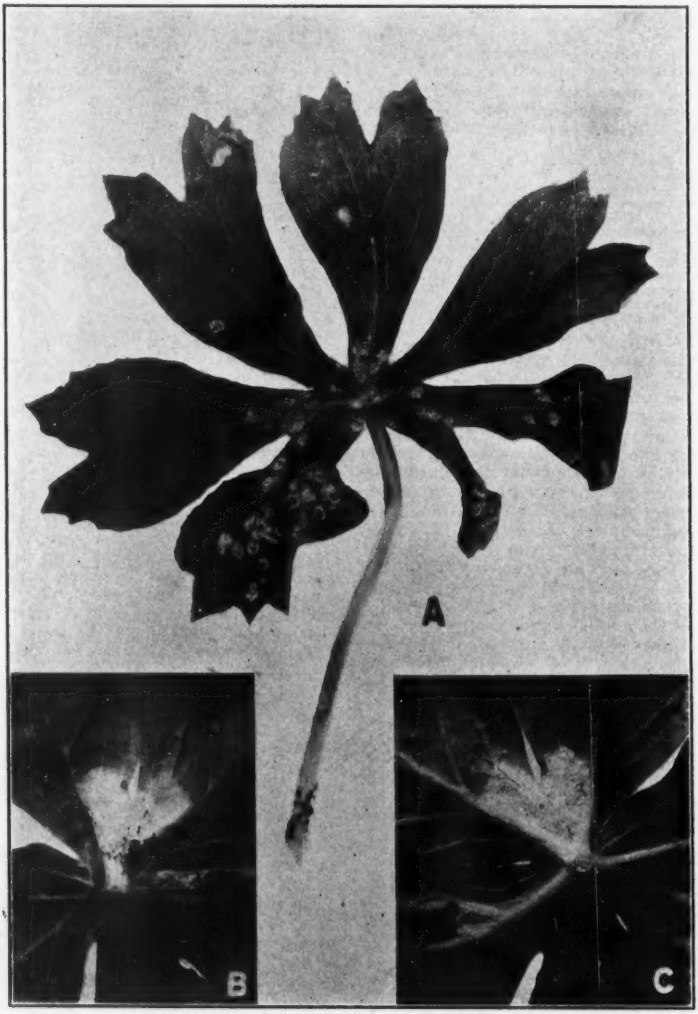
EXPERIMENTS AT ITHACA, N. Y., 1916–1917

One of the authors of this paper (Whetzel) has had Podophyllum rust under observation since about 1906. During 1912 he collected and fixed much of the material on which Olive's cytological work was based and furnished him without reservation all the information gained from the field observations which had then been made. This assistance is freely acknowledged by Olive in the paper referred to above.[4]

The elaborate, though entirely orthodox, explanation of the situation finally made by Olive did not seem to Whetzel adequately to explain the phenomena which had been observed in the field. On this account it was decided to test the validity of Olive's hypotheses by culture experiments. The first of these was conducted at Ithaca, N. Y., during 1916 and 1917.

The plants used for the experiment had been brought several years before from a patch of Podophyllum in which no rust was to be found and were planted on a wooded bank in Whetzel's yard far away from any other patches of Podophyllum. Since the planting was along the path by which he reached the road on his way to the office each day, he was able to determine by careful inspection each year that no rust ever appeared either on the bud scales, stems or leaves of these plants. In the summer of 1916 he collected a large quantity

[4] A detailed manuscript record of these experiments, together with the correspondence which passed between Prof. Whetzel and Dr. Olive on the Podophyllum rust, is deposited in the library of Cornell University under the title, "Notes on the Life History of Puccinia podophylli," by H. H. Whetzel.



A.—Upper surface of leaf of *Podophyllum peltatum* inoculated with teliospores from stem sori. Note abundance of telia in aecial lesions and telia at base of stem
B.—Upper surface of aecial lesion showing telia along the veins. Natural infection
C.—Lower surface of same lesion as B, showing aecia. Natural infection

of Podophyllum leaves which bore the second, or summer crop, of teliospores in abundance, put them between two sheets of window screen and placed this over one end of the established rust-free planting in his yard. This plot had developed so that it was about 8 feet long and rather narrow. The screen packet was about 12 by 18 inches. During the fall and winter the Podophyllum leaves in the screen rotted and the spores fell with the débris through the meshes upon the surface of the soil. Early in the spring of 1917 the empty screen was removed and careful observations were made on all the plants in the plot at frequent intervals as they developed. Telia soon appeared on the sheath leaves and stems of nearly all the plants which came up in the area covered by the screen packet. No rust appeared on plants elsewhere in the bed during the entire season. A seedling in the infected area also developed aecial lesions on the leaf blade in the spring of 1917. Two nearby seedlings showed telia only on the stems. One of these seedlings stood directly under that bearing aecia and when all three were removed on June 4, 1917, it showed the whitish lesions of the developing but unopened summer telia. However, no summer crop of telia appeared on any of the other plants in the patch during 1917. In 1918, while leaf sheath and stem lesions bearing the early telia were common, only a single plant developed an aecial lesion. This was allowed to remain, and later nearly every leaf blade in the patch showed a more or less abundant development of the summer telia. Since that time this patch of plants has been rusted more or less each year, all stages of the rust appearing in the manner usual for this species.

This experiment, while not in itself conclusive, strongly suggests that the interpretations of the life history made by Olive are not in accord with the facts. It would appear from this experiment that the infection on the sheaths and stems, resulting in the early crop of telia, arose directly from the basidiospores developed from the late crop of teliospores which were used as the inoculum and that these teliospores were responsible also for infection on the seedling leaves, resulting in pycnia and aecia. Since the aecial-bearing seedling was removed along with the seedling showing the initial stages of the summer telia, and since no other plant in the patch showed summer telia during 1917, it would further appear that the spring crop of teliospores was responsible the next season for the development not only of another crop of early teliospores on sheath and stem but also for pycnia and aecia later.

EXPERIMENTS AT LA FAYETTE, IND., 1917–1921

Since this experiment was conducted entirely out of doors and the usual objections to such experiments would naturally arise, it was decided to repeat the work with variations, in part at least under controlled conditions, and to conduct this work in connection with the rust investigations under way at the Purdue University Agricultural, Experiment Station at La Fayette, Ind.

EXPERIMENT 1.—During the summer of 1917 patches of Podophyllum were located in the woods, some of which were heavily rusted and some of which showed no rust. An equal number of plants, about 25, were dug in November from each of two plots, one of which was rusted and the other not. The rhizomes were very carefully washed and cleaned of all soil or dead parts and planted in a single row in a vegetable garden (Jackson's), with a stake dividing the two lots. A frame 18 inches by 48 inches made of boards 4 inches wide was placed on the ground in the middle of the row in such a position as to include 5 plants from the rusted patch and 5 from the one which showed no rust. A peck or less of surface soil and débris taken from a patch of Podophyllum which had been heavily rusted during the previous summer was evenly spread over the soil in this frame. No protection was given the plants during the winter.

In the spring of 1918 all 10 plants in the frame showed the early telia on the bud sheaths or stems and later about half of them showed pycnia and aecia in fair abundance on the blades of the leaves. No infection of any sort occurred on the other 40 plants at either end of the frame. The experiment was not continued since the ground was needed for other purposes.

Were the rust perennial in the rhizomes some of the plants outside the frame which had been dug from the rusted patch should have been rusted. The infection on the plants in the frame presumably resulted from the teliospores present in the top soil used as a mulch.

EXPERIMENT 2.—In November, 1917, about 50 rhizomes dug from a patch of Podophyllum which showed heavy infection on nearly every plant during the spring were thoroughly washed.

Some of these were placed in flats, covered with potting soil, and placed out of doors with a heavy covering of straw. Some were potted at once and placed in the greenhouse. The material which was placed in flats was brought into the greenhouse in March, 1918, when the leaves were just emerging from the sheaths. No rust developed on either set of plants, though they were grown to maturity.

In March, 1918, before the buds had swollen to any extent, a second lot of rhizomes were dug from a patch which was known to have been heavily rusted during the previous summer. These were thoroughly washed, potted in potting soil, and allowed to develop in the greenhouse. No sign of rust infection appeared on any of them.

An inspection of the remaining plants in the patch of Podophyllum from which the last-mentioned rhizhomes had been dug was made at intervals during the spring and summer of 1918 and the plants were found to be heavily infected, showing the early development of telia on the sheaths and stems, pycnia and aecia later on the leaves, and finally the late crop of telia on the under side of the leaves.

Stems showing the early telial sori and the attached rhizomes were collected in the spring of 1918 and were studied in an effort to determine the extent of the mycelium. Free-hand sections were made, beginning in the region of the sori and progressing down the stem into the rhizome. The sections were mounted in chloral hydrate and iodine, which furnishes a satisfactory medium for the study of such sections. The mycelium is easily distinguished by this method and was found only in the immediate region of the sori. No mycelium was discovered lower down in the stem or in the rhizome.

This series of experiments taken in conjunction with the one made at Ithaca would seem effectively to dispose of the hypothesis put forward by Olive that the rust is perennial in the buds or rhizomes.

A number of other experiments were considered desirable, however, in order to determine as accurately as possible just what did occur. The question naturally arose as to whether there might be some difference in the teliospores formed early in the season on the stems and sheaths and those formed later from aeciospore infection, either in their ability to cause infection or in the sequence of resulting spore forms. It was also considered desirable to conduct some of the experiments with somewhat more refined methods and under as strict control as is feasible in dealing with growing plants and with a fungus which can not be grown in pure culture.

EXPERIMENT 3.—The telial material which was used for the following inoculation experiments was obtained in the spring and summer of 1917 in the same patches of Podophyllum from which the rhizomes used in the previous experiment were taken. The first material was collected May 28, 1917, and consisted entirely of sheaths and stems bearing the early crop of telia. These were placed out of doors on the surface of potting soil in flats and left till the following spring, 1918. On July 17, 1917, material of the late crop of telia which develop from aecial infection and occur abundantly scattered on the under surface of the leaves was collected and handled in the same way as the sheath and stem material mentioned above. Finally, in the fall of 1917, after the Podophyllum plants had died down and the leaves were more or less disintegrated. surface soil from a patch of heavily infected Podophyllum was collected and placed out of doors to winter. At the same time rhizomes were again collected from a patch of Podophyllum which had shown no infection during the year and were placed in flats, covered with potting soil, and left out of doors with protection during the winter. In March, 1918, these rhizomes were brought into the greenhouse, thoroughly washed, and potted. Some of the pots were given a surface coating of the surface soil obtained from the infected Podophyllum patch, some were mulched with the soil and stems from the flat prepared in May, 1917, and some with the soil and leaves from the flat prepared in July, 1917, as described above. It should be pointed out that the sheaths, stems, and leaves had largely disintegrated after overwintering and most of the teliospores were mixed in the surface soil of the flats in which they had been kept; hence the reason for using the soil as a mulch. As the buds of the potted plants developed they pushed up through this mulch and became exposed to infection.

The results of this experiment were as follows: In one of the pots mulched with soil, sheaths, and stems bearing the early teliospores, pycnia and a few aecia developed on the leaves of one plant and pycnia and aecia together with a few telia immediately associated with the aecia on another. In the pots mulched with soil and leaves bearing

the late crop of teliospores, four plants showed pycnia and aecia on the leaves in numerous spots, some of which on all four plants in later stages of development showed accompanying telia. In the pots mulched with soil from the infected patch one plant showed a few pycnia and abundant telia on sheath and stem, together with pycnia and aecia on the leaves in numerous spots in association with which telia were not uncommon, and the other plant showed numerous spots with pycnia and aecia, with some of which were associated telia. In all cases where telia accompanied the aecia on the leaves they were most commonly found on the veins which were involved in the areas of aecial infection. A control series of pots in which the rhizomes were mulched with ordinary potting soil showed no infection of any sort.

EXPERIMENT 4.—In this experiment overwintered teliospores from the late crop on the leaves, which by previous test were known to be germinating, were sown at three different dates on Podophyllum plants taken from an uninfected patch. This work was all done in the greenhouse. The first sowing was made on April 27, 1918, on leaves and stems of four plants, three of which had the folded leaves well out of the sheaths and the fourth just emerging. The result showed development of pycnia and aecia on leaves of all plants and telia on the stem of one. Epiphyllous telia developed in a number of the aecial areas, mostly on the veins. The second sowing was made on May 6, 1918, on six plants of Podophyllum all of which were well out of the sheath, with the leaves partly expanded. Pycnia and aecia were developed on the leaves of all plants. Some of the aecial lesions on each plant showed telia in immediate association. In one case telia were developed in association with pycnia without aecia being present. In the third sowing on May 11, made on the leaves of more mature plants, numerous lesions bearing pycnia and aecia developed on two of the plants. Telia were also developed later in association with the aecia on a majority of the spots. On both plants a few spots containing aecia developed in association with which no pycnia were observed.

EXPERIMENT 5.—This experiment dealt with the infection from aeciospores. Three sowings were made under control conditions in the greenhouse. The first sowing was made on May 28, 1917, using aeciospores collected in the field from plants which showed only aecia and with which no pycnia were observed. The inoculation was made on the expanded leaves, and fully mature telia developed on June 9. The second sowing was made on May 3, 1918, using aeciospores from plants collected in the field on which the aecia were accompanied by pycnia. Sowings were made on one mature plant and three younger plants. An attempt was made to inoculate the sheaths and stems as well as the leaves. Telia appeared, however, only on the leaf blades of the three younger plants, being fully mature on May 20. A third sowing was made on May 10, 1918, using aecia obtained from the inoculations described in Experiment 3. The inoculation was made on several plants in various stages of maturity. Telia developed only on the leaves of the younger plants.

In all of these sowings the telia obtained were of the type occurring gregariously in spots on the under side of the leaves, commonly found in the field in midsummer, and referred to in this paper as the late crop of telia.

These experiments confirm those of Arthur (*1*) and effectively dispose of the idea that repeating æcia might be present in the life history of the Podophyllum rust.

LATER EXPERIMENTS.—During 1919, 1920, and 1921, other experiments were conducted, which confirmed the results of those outlined above in all details. In a few cases telial material which was observed to be germinating in hanging-drop tests was transferred to the plant. The results were the same as where less refined methods were used.

It may be noted that only a few records of infection on the sheath leaves are made in these experiments. This, it should be explained, is due to the fact that some difficulty was encountered, under rather dry greenhouse conditions, in preventing the sheaths from drying up before the telia developed. In many such cases, however, evidence of infection was observed, and in the later experiments of 1919 to 1921, this phase of the problem was given special attention.

SUMMARY OF RESULTS OF EXPERIMENTS

A careful analysis of the results of these experiments shows that the writers have obtained the development of telia on sheaths and stems, and pycnia and aecia with associated telia on the leaves, by inoculating with germinating teliospores of both the early and the late crops.

No basis was found for the idea that the rust is in any sense perennial or that any condition approaching an "unlimited infection" is evident. It would appear that all of the structures develop from a localized mycelium and that this mycelium in all cases (except the late crop of telia) arises from basidiospore infection. It is also evident that the first spore structure borne on this mycelium may be either telia, or pycnia accompanied by aecia, and in rare cases aecia without pycnia.

These experiments when taken together with field observations made at Ithaca, N. Y., and La Fayette, Ind., would seem to make necessary an interpretation entirely different from that made by Olive.

LIFE HISTORY AND SEQUENCE OF SPORE FORMS

It seems desirable, therefore, as a basis for further discussion, that the writers here set forth in some detail what they conceive to be the regular sequence of events in the life history of this rust.

In the spring, at the time when the buds of the Podophyllum plant are emerging from the ground, the teliospores of *Puccinia podophylli* are present in the surface layer of soil around the developing buds. These teliospores are derived both from the spring crop of telia on leaf sheaths, stems, and sepals and those associated with aecial lesions, and from the summer crop produced on the leaf blades. They have either fallen to the ground during the previous summer, as the telia are of the pulverulent type, the pedicles breaking close to the spore, or they have been liberated by the rather complete disintegration of the host tissues. The spore wall is beset with sparsely scattered rather long spines which would serve to prevent the spores from being carried too deeply into the soil or washed away during heavy rains.

At the time when the sheathed leaf buds begin to push their pointed tips above the surface of the soil, these teliospores (of both crops) begin to germinate in the normal way for teliospores, that is, by the development of a typical promycelium and sporidia. The scale leaves form a sheath about the base of the stem, through which the young plant emerges. These scale leaves usually extend slightly above the ground level. The lobes of the two peltate leaves of the flowering stalk are folded about the stem in a convolute manner and the single blossom bud is partly exposed.

The basidiospores fall upon the portions of the plant which are exposed in the early stage of development and infection results. The sheath leaves or bud scales are the first organs exposed. As the aerial stalk pushes forth from within the enfolding bud scales, both the base of the stem and the leaf blade are also exposed to infection. The upper part of the stem is rarely infected as it long remains protected by the enfolding leaf blades. The two sepals of the flower are, however, not uncommonly infected, for they are usually partly exposed as the young plant emerges (Pl. 1, A and B).

The period of basidiospore production (that is, teliospore germination) apparently is relatively early and short. Very numerous infections occur on the scale leaves and on the base of the stems. This is perhaps due to the fact that they are nearer the soil surface and in the more effective zone of basidiospore dissemination. At Ithaca it has been noted in some seasons that only certain scale leaves, such, for example, as the second from the top, show infection. This observation (Whetzel's) was referred to by Olive as a "curious fact." The explanation is, however, comparatively simple. These "second" scale leaves were the only ones exposed in the particular patch under observation at the time of inoculation. There are three or more of these buds scales at the base of the stem. The top scale had not emerged from within the protecting outer second scale and the shorter third scale was still covered by leaf mold. It has since been observed, in the same patch, that all the scales and the base of the stem may be infected. It would appear that these differences are the result of seasonal variation in the coincidence of basidiospore production and development of the host and of variations in the extent of exposure of the bud scales above the surface of the leaf mold.

From the basidiospore infections on the scale leaves, the base of the stem, and the sepals, telial sori are developed almost exclusively. Pycnia and aecia are occasionally found intermixed with the telia, the latter usually occurring singly. Both are, however, rather rare, and by far the greater number of lesions include telia only. In one case noted at LaFayette an isolated lesion on the stem bore a group of pycnia surrounded by a ring of telial sori, exactly similar in appearance to many true microforms of Puccinia.

The occasional development of pycnia and aecia among the telia on sheath

leaves is readily understandable when one has the fresh specimens in hand. These always occur on the thicker, fleshier parts of the sheaths. These parts mature more slowly than the margins, thus simulating the conditions obtaining in the longer-growing tissues of the leaf blade where aecia normally develop from this primary infection, as noted below.

The infection on the sepals is not commonly observed because they soon drop off. If a search is made, however, at the right time, they can usually be found in considerable abundance on the ground among flowering stalks, and if infection is abundant in the patch on stems and sheath leaves these fallen sepals will almost invariably be covered with telia. Infected sepals still attached to the plant have, however, been found both at La Fayette and Ithaca (Pl. 1, A).

When basidiospore infection occurs on the blade of the leaf, aecial lesions almost invariably result. These show at first pycnia on the upper surface, followed shortly by the aecia below. It should be emphasized that the basidiospores which cause this infection may result from the germination of either the early or late crop of teliospores of the previous season.

The aecial lesions are rarely evident until after the teliospores on the sheath leaves, base of stem, and sepals have begun to mature. Fully developed aecia are seldom found earlier than a week after an abundance of mature teliospores appears on sheaths and stalks. It is obvious that these early telia could not have been produced from aecial infection. The delayed appearance of the aecia is perhaps due to the slower development of the fungus in the less rapidly maturing tissues of the leaf blade.

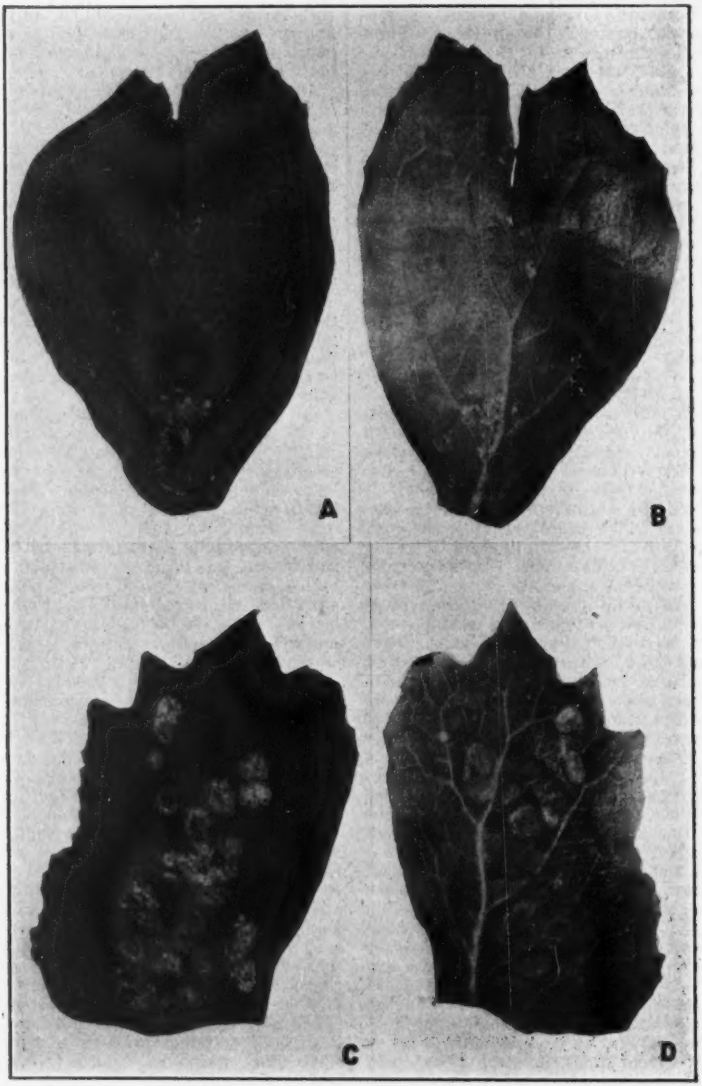
As the aecial lesions begin to mature, that is, when the cups are open and the spores are being discharged, one often finds, usually on the upper surface, about the margins of these lesions or more commonly on any larger veins which may be included in the lesion and even in the center of the spot among the pycnia, a rather abundant production of telial sori along with more or less development of epiphyllous aecia (Pls. 2 and 3). These telia are like those developed on sheath and stem and are certainly developed on the same mycelium as the aecia. A careful study made by one of the writers (Jackson) of the sori in such lesions has revealed the fact that occasionally a greater or less production of chains of aeciospores may be found in these telial sori. In similar situations aecia may occasionally be found with a few teliospores in the margin. In one specimen studied a sorus was found, one-half of which consisted of aeciospore chains and one-half of teliospores.

Occasionally aecial lesions may be found in which pycnia do not develop and quite commonly only a very few pycnia are found. When infection takes place on leaves which are relatively quite mature the number of telial sori formed may be greater than the number of aecia (Pl. 3, A and B). In one instance noted in the culture results, telia accompanied by pycnia, but with no aecia present, resulted from basidiospore infection on the leaves. Such a condition exactly parallels the normal result when infection occurs on the sheaths and stems, and is comparable to the usual condition of a micro-Puccinia.

It has been observed at Ithaca, N. Y. (Whetzel), that a very much smaller number of leaf blade infections resulting in aecia occur than of infections on scale leaves and stems resulting in telia. Patches of Podophyllum have often been noted in which the early crop of telia on sheaths and stems was almost universal, but in which no aecial lesions on the leaf blades developed during the season. In that locality no cases have been observed where more than a small percentage of plants showed aecial infections. This, however, is not the case at La Fayette, Ind. Aecial lesions on the leaves are usually found in considerable abundance in infected patches. It would be interesting to have data on this point from other sections of North America, particularly from regions at the northern limit of the range of the host species.

The aeciospores are scattered by the wind and cause infection of the surrounding expanded leaves of the Podophyllum plants. This infection is usually very profuse and general, and after a period of ten days or two weeks angular yellowish spots appear, on the under side of which are developed the gregarious, pulverulent telia bearing the second or summer crop of teliospores (Pl. 4, B). These mature and fall to the ground to mingle with those of the early crop, which have already been largely disseminated.

Reference has repeatedly been made to the two crops of teliospores. Those which appear early in the season on the sheaths, stems, sepals, and in association with the aecia on the leaves form the first crop, and those which arise from the infection of aeciospores form the second crop. There is, however,



A.—Upper surface of leaflet inoculated when quite mature with overwintered teliospores o late or summer crop. Note abundant production of telia and scanty infection

B.—Lower surface of same leaflet shown in A. Note development of telia almost to the exclusion of aecia

C.—Upper surface of leaflet inoculated when young with overwintered teliospores from the early crop on the stems. Note abundant production of telia among the pycnia and the vigorous infection

D.—Lower surface of leaflet shown in C. Note abundant development of aecia with an occasional telial sorus. Contrast with B

in addition to the difference in seasonal appearance, a noticeable difference in the character of these two sorts of telia, difficult to describe but easily recognizable when one has the specimens before him. In the early crop, the telia are usually somewhat larger, less definitely circular in outline and somewhat longer covered by the cinereous epidermis. They also cause a slight but distinct hypertrophy of the host tissue similar to that produced by the aecia. When on succulent tissue they also appear to have their origin much deeper in the tissues. This difference is perhaps best brought out by comparing Plate 1, A and B with Plate 4, A and B.

It seems probable that this difference in type of sori is correlated with the fact that the early crop of telia on sheaths, stems, and sepals, as well as those which occur in association with the aecia, have a gametophytic origin, while the late crop which develops from aeciospore infection is sporophytic in origin.

The writers have been unable to obtain any evidence either from observation or cultures to show that this species possesses secondary or repeating aecia. Cultures conducted both in the field and in the greenhouse under control conditions have shown that the aeciospores give rise to the summer crop of telia.

SUMMARY OF LIFE HISTORY

The teliospores of both the early and late crops are functionally and morphologically indistinguishable and the basidiospores developed on the promycelium of either sort may, after overwintering, cause infection on any exposed portion of the Podophyllum plant. When infection takes place on the sheath leaves, stems, or sepals, telia are at once produced. They may or may not be accompanied by a few pycnia or aecia. When, on the other hand, infection takes place on the blade of the leaf, pycnia followed by aecia are developed. Aecia may develop without accompanying pycnia. Telia similar to those on sheaths and stems may or may not accompany the aecia on the leaves, and when present develop from the same mycelium as the aecia.

The late or summer crop of telia develops from aeciospore infection. There is no evidence of repeating aecia.

GENERAL DISCUSSION

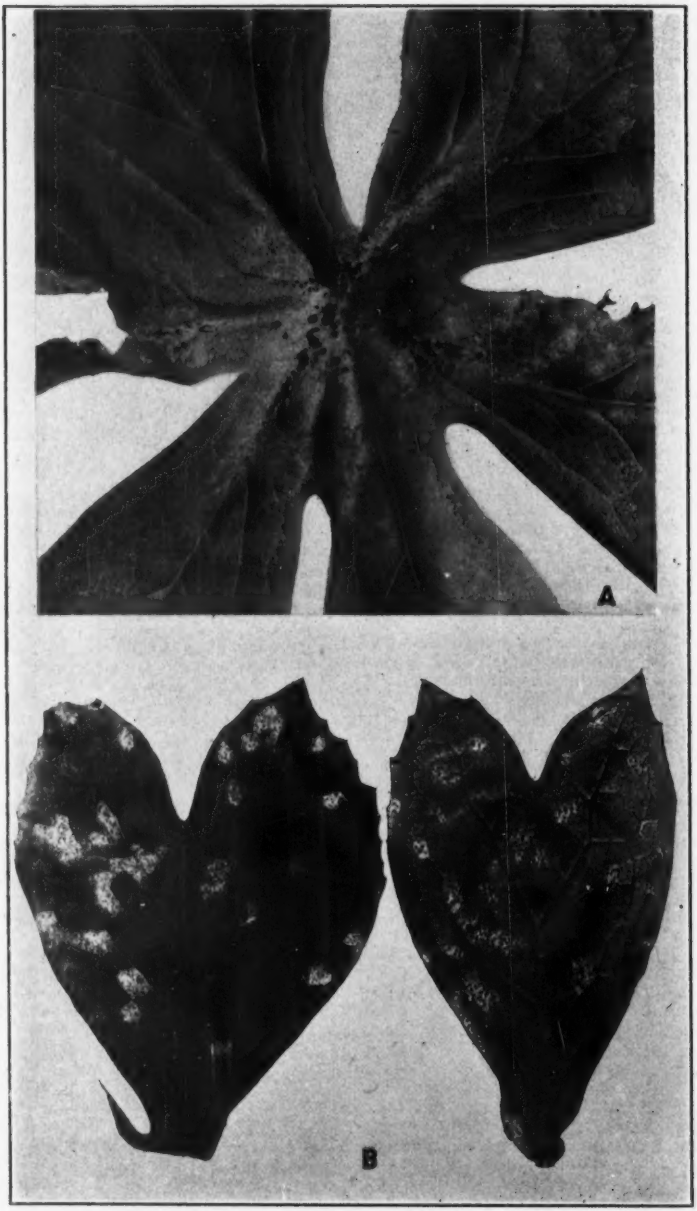
It is evident from the above that the writers' interpretation of the life history differs radically from that of Olive. It now becomes necessary to attempt to correlate this new interpretation with Olive's cytological observations. The writers have at present no basis for criticizing these observations nor do they see any reason, for purposes of discussion, for not accepting them as matters of fact.

It must be admitted, however, that in view of the experimental results recorded above, it would be highly desirable that the cytological situation in *Puccinia podophylli* be reinvestigated. It is apparent that we are dealing with a rust showing considerable plasticity in its development since from basidiospore infection teliospores are the first spore form produced under some conditions, while under others, pycnia followed by aecia occur.

It will be recalled that Olive found a small amount of uninucleate mycelium with the developing telial sori on the sheaths and an abundance of such mycelium in lesions on the leaves, but that the aeciospores as well as the teliospores developed on a binucleate mycelium. No so-called sexual fusions were observed to take place at the base of the aecial cups. It was assumed that all the telia and aecia were formed on a perennial binucleate mycelium and the pycnia were formed on a perennial uninucleate mycelium. The aecia were then assumed to be secondary in nature and sexual fusions would not be expected. They were to be expected, according to this view, in the primary aecia which would originate from basidiospore infection. These Olive assumes he had not seen, and evidently considered it doubtful whether they would be found to be present in the life history.

In view of the evidence already presented it would hardly seem necessary to consider seriously the possibility of a systemic perennial mycelium in the case of this parasite. However, the paper by Olive has given this theory such general acceptance that it seems necessary to emphasize the fact that the writers have not been able to obtain the slightest evidence that the rust is in any sense perennial, or even systemic, in the host plant.

According to the view of the writers, accepting the cytological findings of



A.—Upper surface of leaf showing aecial lesion which involves the disk and the veins. Note the pycnia and the abundant development of telia. Natural infection
B.—The late or summer crop of telia on upper and lower surface of leaves. Compare with A and with Plate 1, A and B. Natural infection

Olive, the conjugate condition may be assumed to arise on the mycelium before the primordium of the sorus develops, or at least in a very early stage of its development. In connection with the sori on the sheaths, stems, and sepals, the change from a uninucleate to a binucleate condition would be expected to take place soon after infection, which would account for Olive having found uninucleate mycelium only in small amount. On the leaves, however, the change would be expected to take place later, after the pycnia are formed, and hence, as Olive found to be the case, a considerable mass of uninucleate mycelium would be expected.

Once the binucleate condition has been established in the mycelium there are no difficulties from a cytological point of view as to the spore form produced, since both aeciospores and teliospores arise from binucleate cells. It is very likely that the type of spore produced is determined by the nutritional conditions prevailing in the host. However, it should be borne in mind that the tendency to an unstable condition is quite certainly inherent in the rust itself and the nutritional factors are best interpreted as secondary, serving primarily to explain the situation as we find it and in view of our present, perhaps incomplete, cytological knowledge.

That telia are the first structures developed from infections on the sheaths, stems, and sepals is perhaps correlated with the influence of the rapid maturity of the tissues of these organs and the nature of the available nutrient. This influence was recognized by Olive. He used it, however, to explain why telia were formed instead of "secondary" aecia on the "perennial" sporophytic mycelium.

The occurrence of telia in association with the aecia on the leaf blades, which has been repeatedly mentioned, is readily correlated with Olive's cytological observations and can best be explained also by the factor of food relations. Olive finds that the aecia are borne on a binucleate mycelium. It would appear quite logical to expect that this same mycelium might produce telia when the factors which determine teliospore production become operative.

The development of telia in association with aecia usually occurs sometime after the majority of the aecia are mature. It would seem reasonable to suggest that the development of telia under these conditions may be due to the depletion of the local food supply by the mycelium during the development of the aecia and aeciospores, or directly to the more mature condition of the tissues. Perhaps, however, their formation is best explained by a combination of these two influences. In some cases the telia that develop in association with the aecia appear practically simultaneously with them. This is especially true when the lesion involves the midrib or one of the larger veins. In such cases the explanation is similar to that given above to account for the development of telia only on stems, sheaths, and sepals. The tissues of the veins and midrib are quite comparable in the character of the food supply to that of the stem. It has already been noted in the discussion of the life history that when mature leaves are infected with basisiospores, telia may predominate over the aecia in the resulting lesions and in rare cases may be formed exclusively.

It has been repeatedly observed in connection with many long-cycle rusts, that as the hosts approach maturity there is a gradual reduction in the development of repeating spores and a corresponding increase in the development of the teliospores either in the same or separate sori. It would seem that this situation exactly parallels that in the Podophyllum rust except that since there are no repeating spores the teliospores developed in association with the aecia normally occur in separate sori. As noted in the discussion of the life history, however, teliospores may rarely develop in the aecial cups.

It is important to note, however, that only a few other cases have hitherto been observed where aecia have been replaced by telia. In most rusts the maturity of the tissues affects aeciospore production largely by reducing the number of aecia produced or the quantity of aeciospores. It has been repeatedly observed in the laboratory at La Fayette in connection with heteroecious culture work that when over-mature leaves or those in a poor growing condition are inoculated, while pycnia may be formed to some extent, few if any aecia develop. The fact that aeciospores are replaced by teliospores in the Podophyllum rust is therefore another indication of the plastic and unstable condition of this species.

The assumption that the conjugate condition arises at an early stage in the development of the mycelium can also be used to explain the fact that aecia may occasionally be developed without the pycnia. In such cases the change may have taken place

very early, before a sufficient mass of mycelium has been formed to enable the pycnia to develop. Either aecia or telia might then develop on the mycelium as the first spore form following infection, dependent on the available food supply or the maturity of the tissues.

It is well to recall at this point that the telial sori on stems, sheaths, and sepals strongly suggest the normal situation in microforms, and it is enlightening to review briefly the cytological situation which has been found in the species of short-cycle Puccinia and Uromyces which have thus far been studied.

It is convenient to consider these in two groups. In the first the primordium of the telium is made up of uninucleate hyphae, and the conjugate condition arises as a definite process, by cell fusion or nuclear migration, in a manner similar to that found in aecia. This is the general situation in the following species: *Puccinia (Nephlyctis) transformans* Ellis and Ev. investigated by Olive (*5*), *Puccinia (Polythelis) fusca* (Pers.) Wint. by Pavolini (*7*), *P. malvacearum* Bertero by Werth and Ludwigs (*8*), *P. buxi* DC. by Moreau (*4*) and *Uromyces scutellatus* (Schrank) Lev. and *Puccinia rossiana* (Sacc.) Lagh. by Kursanov (*3*). *Uromyces laevis* Körn., studied by Kursanov, probably also belongs in this group, but the actual process of the formation of the conjugate condition has not been observed.

In the second group the primordium of the telium is made up of binucleate hyphae and the vegetative mycelium is also primarily binucleate. The transition from a uninucleate to a binucleate condition in these forms has unfortunately not been observed, but it is assumed by the authors that it occurs very early in the vegetative growth of the mycelium. This group includes *Puccinia fergussoni* Berk. & Br., *P. asarina* Kze., *P. aegopodii* (Schum.) Mart., *Puccinia* sp. (*P. conferta* Diet. & Holw.?) on Artemesia, and *Uromyces gagae* Berk. as investigated by Kursanov (*3*) and *P. adoxae* Fuck. and *Uromyces scillarum* (Grev.) Wint. by Blackman and Fraser (*2*).

It should be pointed out that, except for *Puccinia malvacearum*, *P. buxi*, and *P. rossiana*, the species of the first group normally develop pycnia; while in those of the second group, without exception, pycnia are normally absent.

Uromyces ficariae Wint. is especially interesting in this connection. Blackman and Fraser (*2*) record that—

> the general mycelium appears to exhibit single nuclei, but the mass of mycelial hyphae round about the teleutospore sorus as well as those directly connected with teliospore formation appear to have conjugate nuclei.

They did not find how or where the change took place. Moreau (*4*), however, found all the mycelium uninucleate and the binucleate phase beginning in lower cells of the telial primordium. Kursanov (*3*), on the other hand, more nearly confirms the findings of Blackman and Fraser (*2*). He finds, however, only a small amount of uninucleate hyphae, the vegetative mycelium being prevailingly binucleate.

A more detailed review of the literature of this subject would show that in the first group there was considerable variation in the amount of sporophytic tissue developed between the origin of the binucleate condition and the formation of teliospores.

We apparently have, therefore, in some forms of short-cycle rusts a very short sporophyte, while in others the origin of the conjugate condition has arisen at varying distances back from the mother cell of the teliospores, sometimes only a little way, sometimes far, possibly even near to the point of infection by the gametophytic basidiospore.

It seems to the writers that this cytological situation, especially as found in the second group of species mentioned above, parallels very closely that described for *P. podophylli* by Olive. It is unfortunate that in these short-cycle forms the fusions have been observed only in the cases where the change takes place at the base of the telium. This circumstance, however, serves to point out the wealth of problems awaiting solution in this field, and it is hoped that students of cytology will soon give us the necessary link to make the chain of evidence complete.

PHYLOGENETIC CONSIDERATIONS

It is pertinent to ask what is the significance of the peculiar life history as shown by the Podophyllum rust. Without attempting at this time to go into the evidence which has determined their position, it may be stated that the writers of this paper are among those who believe that, regardless of what the most primitive rust may have been, the long-cycle species in the group Pucciniaceae at least are the older and that the short-cycle forms as exemplified by the microforms of Puccinia and Uromyces are derived or reduced forms and are relatively more recent.

It follows, then, that during the process of development from a long to

a shorter type of life history some intergrading conditions are to be expected. It is not at all surprising also to find evidences of a profound readjustment and an apparently unstable condition in the nuclear phenomena in some forms.

The writers believe that *Puccinia podophylli* is a form which still exhibits evidences of the sort of changes which may have taken place in the development of the reduced forms from the more complex.

SUMMARY

1. *Puccinia podophylli* shows no evidence of being perennial or systemic in the host.

2. The early crop of teliospores which occur on the bud scales, stems, and sepals preceding the aecia arise directly from mycelium produced by basidiospores from overwintered teliospores and are usually not accompanied by pycnia.

3. The aecia which normally develop on the blade of the leaf also arise in a similar manner from the same source. Pycnia are usually found associated.

4. The late or summer crop of telia are produced on mycelium developed from infection by aeciospores.

5. There is no evidence of repeating aecia in this species.

6. Basidiospores from either the early or late crop of teliospores may result in the production of either the early telia or the aecia.

7. Telia may develop in association with the aecial lesions and arise directly from the same mycelium.

8. When mature leaves are infected telia may predominate over the aecia, with or without the development of pycnia.

9. *Puccinia podophylli* exhibits evidences of being in an unstable or plastic condition as to life history.

10. It is suggested that the food conditions of the various tissues invaded have an important influence on the spore form developed.

11. This species is believed to be a form which still exhibits evidences of the sort of changes which may take place in the evolutionary development from the complex to the simpler forms of life history.

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EFFECT OF HEIGHT OF CHIPPING ON OLEORESIN PRODUCTION [1]

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INTRODUCTION

"Gum," as the oleoresin from the living slash and longleaf pine trees of the southern United States is called, is obtained by cutting a gash or "streak" across the grain of the outer sapwood at the butt of the tree. The depth into the tree to which this cut extends and the height of the chip of wood removed have varied in commercial practice, and still vary widely. A new cut has to be made, generally at weekly intervals, to freshen the exposed surface and secure a flow of gum. The successive cuts or chippings, one close above the other, constitute the "face." (See Pl. 1.) During a season's work, generally between March and December, about 32 chippings or streaks are cut.

The objection of some timber owners to turpentining virgin timber is due to the very injurious methods of chipping which have prevailed all too widely. A large amount of timber has been killed, injured, or at least its grade unnecessarily lowered, in this way.

For some time past the Forest Service of the United States Department of Agriculture has been testing operating methods for the purpose of determining ways of improving turpentine production and at the same time of conserving timber. The administration of the Florida National Forest has indeed demonstrated over a considerable period and on a commercial scale the beneficial results that can be obtained on mature longleaf pine timber by the use of a streak which removes a chip ½ inch deep and ½ inch high each week,[2] a more conservative practice than that obtaining in many private operations. Tests were also started in 1923 and are now under way at the substation of the Southern Forest Experiment Station at Starke, Florida, to determine the effect of different carefully controlled methods of chipping on second-growth slash and longleaf pine.[3] The test reported here is one of still another series[4] which has been conducted for a number of years by Dr. Austin Cary, logging engineer (Branch of Forest Management), in which the writer and, in this case, Deputy Supervisor E. R. McKee and W. H. Graham, commercial turpentine operator on the Florida National Forest, also cooperated. Both in tests and in commercial turpentining many indications have pointed to the fact that removing less wood produces conditions in the tree which favor high sustained production.[5] "Low" chipping permits a reduction in the size of the scar cut each year, thus lessening the amount of possible degrade. It also lengthens the time during which a given crop may be operated, if so desired.

Therefore, since the results from "low" chipping indicated decided operating advantages, but since no data on directly comparable stands were available over a sufficiently long period to be conclusive, the turpentining test described herein was instituted. It was conducted in connection with an actual commercial operation, the chipping being done by the regular worker assigned to the tract, and the gum, after being weighed, was collected and stilled together with the other gum

[1] Received for publication July 23, 1924. A report of a test made by the Forest Service in 1923 to determine the effect of different heights of chipping in turpentining longleaf pines.

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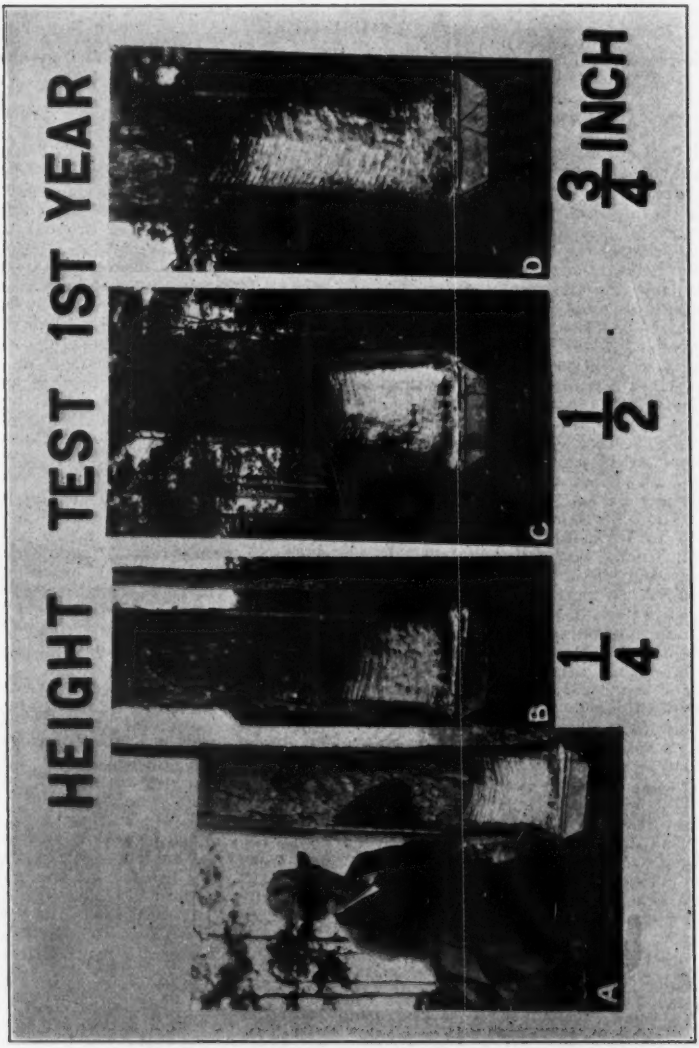
[5] Gerry, E. OLEORESIN PRODUCTION. U. S. Dept. Agr. Bul. 1064, 46 p., illus. 1922. —— RECENT OBSERVATIONS ON THE EFFECTS OF TURPENTINING ON THE STRUCTURE OF SECOND-GROWTH SLASH AND LONGLEAF PINES. Jour. Forestry 21: 236–241, illus. 1923.



A, B.—Low faces, Group 1
C.—Medium high faces, Group 2. Standard Forest Service practice
D.—High faces, Group 3. Common commercial practice

obtained from the area. The test probably will be continued until 1927. Similar tests will be conducted by Dr. Cary and the writer in cooperation with other interested operators. Various types of slash and longleaf pine timber in widely scattered localities in the South are to be studied. Practically stated, the object of this investigation, of which the test described below is a part, is to determine whether there is any good reason why operators should not cut "lower" faces; that is, remove at each cutting less wood than is now customary.

DESCRIPTION OF THE TEST

CHARACTER OF TREES SELECTED

The 60 longleaf pine test trees constituting three matched groups are located near a main road in the Florida National Forest and are easily accessible from the Ranger Station at Camp Pinchot, Valparaiso, Fla. The tract in which they stand had been set aside to be worked commercially for turpentine, beginning in 1923. Conditions of soil and general site apparently are comparable for all. The individual trees were matched by diameter measurement breast high and by visual inspection for similar external features, such as crown density, character of bark, and absence of wounds or fire scars.

It is realized that 60 trees is a small number. The results and conclusions drawn are, consequently, to be considered as indicative only. The helpfulness of these small tests, however, has been clearly demonstrated. They offer opportunities for careful detailed selection and matching of individual trees which larger ones do not, so that they may be compared as closely as possible. This was true in the test described, where both external features and internal structure run parallel to a fairly satisfactory degree in the groups.

The test trees were divided into three similar plots or groups of 20 each, to be chipped at different heights. They were distinguished by suitable markings, that is, one spot of white paint on the bark of each tree in Group 1 and two and three spots, respectively, for each tree of Groups 2 and 3. The average diameter breast high for the three groups was practically the same (11.5 inches), with individual variations ranging between 9 and 14 inches. The number of annual rings in the half inch of wood next the bark, counted on chips removed during the turpentining, showed group averages of 15.6, 14.6, and 18 rings, respectively. Groups 1 and 2 were selected on November 24, 1922. The third group, representing the commercial practice of many operators, was added for observation on April 9, 1923.

A view showing some of the Group 1 trees which are generally typical for the stand in the test is shown in Plate 3. The timber is not young second-growth. It is generally uniform in character, typical of much that is now being worked, but is not to be classed with fast-growing young longleaf pine on better soil. Neither is it like some of the old, over-mature trees which may be found in this locality. It presents a healthy external appearance and a normal wood formation, as is indicated by the number of rings per inch, shown in the accompanying photomicrographs (Pl. 2).

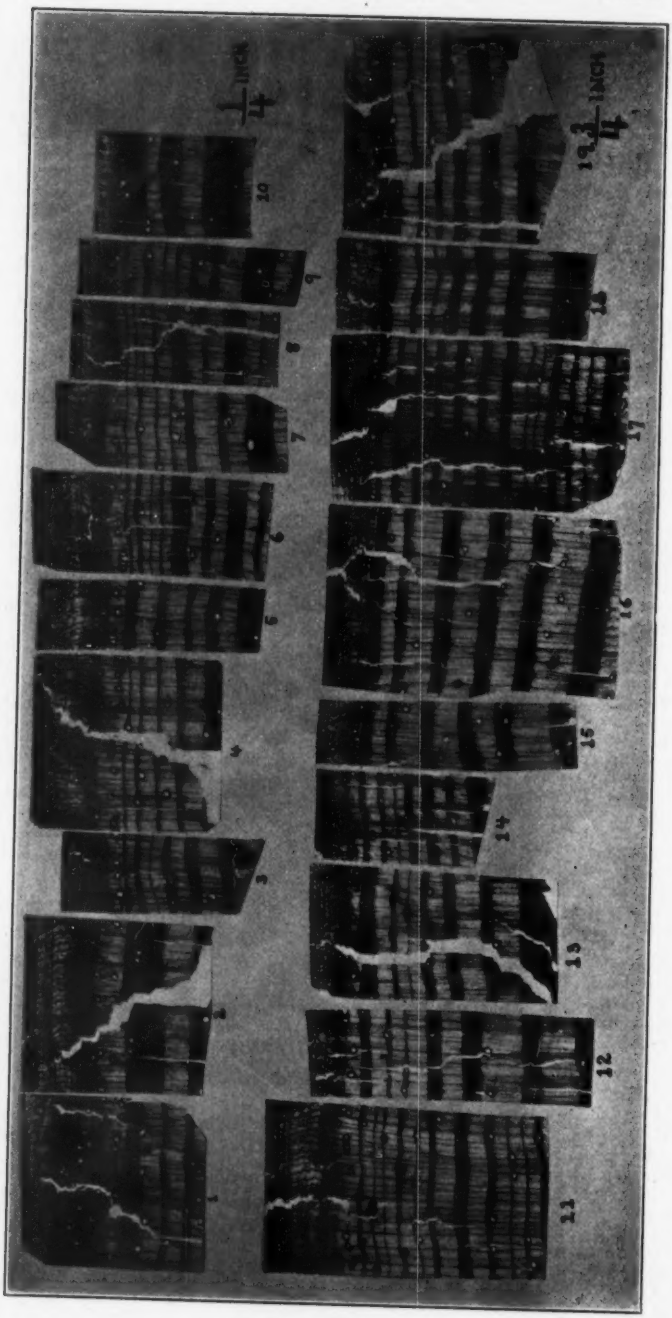
METHODS OF CHIPPING

HISTORY OF FIRST YEAR'S WORK.—The usual advance streak was cut on all trees three or four weeks before the regular chipping, which began on February 17, 1923.

Because of the Deputy Supervisor's illness, the first six streaks were cut without special supervision, ½ inch high, according to the standard practice of the Forest Service, and comparative test chipping was not regularly begun until April 9. Consequently, on that date the faces were an inch and a half higher than was intended for Group 1 and lower by the same distance for Group 3. It chanced, moreover, in surveying the commercial crop[6] lines through the tract that the trees situated in Group 2 were included in a separate crop from the other test trees, so that at first they were chipped by a different workman and later in the week. This would tend to make the yield at the first dipping appear unduly low for Group 2. After June 1 it was arranged that all trees should be chipped on the same day by the same man. Collection of gum (dipping) occurred at the intervals noted in Table I.

The faces are all placed low on the trees, as is the regular practice on the Forest, with the first streak 7 inches or less from the ground. Regular chipping for the year stopped about November 8, 1923, at 32 streaks, but a thirty-third streak was cut to obtain material for microscopic study. At the end of the season the faces were scraped. The yields of gum and

[6] A "crop" is approximately 10,000 faces, or about the number that one man will chip in a week.



(For explanatory legend see p. 85)

"scrape" obtained are shown by weight in Table II.

HACK USED.—Chipping was done with a No. "0" hack, a tool smaller than that generally used. With this it is easier to cut a light chip.

DEPTH OF CHIPPING.—All 60 trees were chipped to the same depth, nominally one-half inch, which has been found successful with this type of timber.

HEIGHTS OF CHIPPING COMPARED.—On the 20 trees in Group 1 a chip as nearly as possible ¼ inch high was removed each week. This is much less wood (in the vertical direction) than is now removed in ordinary commercial chipping, though frequently a chip no higher than this will be removed when the faces are high and a "puller"[7] has to be used.

The 20 trees in Group 2 were chipped ½ inch high each week, according to the standard practice of the Forest. So skilled have the chippers on this forest become that when using an "0" hack they easily and accurately carry on this light chipping and even tend to remove a chip slightly less than ½ inch high. Such chipping has already been found to produce desirable results on a commercial scale.[8] The Group 2 test chipping averaged 0.45 inch for the 1923 season. (See Table I.)

On the 20 trees in Group 3, "high" chipping, ¾ inch per week, was practiced. This corresponds to work now being done in many commercial operations

WIDTH OF FACE.—The average width of the face at the end of the 1923 season was 9.6 inches for Groups 1 and 3 and 9.3 inches for Group 2.

With the overcoming and adjusting of the few slight difficulties and irregularities described above, the test progressed very satisfactorily to the end of the season, and has been resumed in 1924. In Plate 1 are shown typical faces as they appeared on November 24, 1923.

YIELD OF GUM IN RELATION TO HEIGHT OF CHIPPING

RESULTS FROM THE TEST

In Table II are recorded the weights of gum obtained from the three groups of trees during the 1923 season. The average yield per streak per tree at each dipping is exhibited graphically in Figure 1.

With the yield of Group 1 taken as a standard, Group 2 fell below it 8.4 per cent in amount of gum (dip) obtained and 7.2 per cent in amount of dip and scrape combined. Group 3 as compared with Group 1 was 10.5 per cent lower in dip but only 4.9 per cent lower in combined dip and scrape. With Group 2 (Forest Service practice) taken as a standard, Group 3 (common commercial practice) fell 2.5 per cent below in yield of dip; but if dip and scrape combined are considered, Group 3 was 2.7 per cent higher (for the first year) than Group 2.

TABLE I.—*Average height of faces desired and obtained in a chipping test on longleaf pine, Camp Pinchot, Fla., 1923 (measured on 32 streaks)*

Height of cut	Group 1	Group 2	Group 3
Total height face (inches):			
Contemplated	8.0	16.0	24.0
Actual	10.7	14.4	21.4
At test rate	[a] 9.2	14.4	[b] 22.9
Average height streak (inches):			
Asked	0.25	0.50	0.75
Obtained	0.28	0.45	0.71

[a] Actual height minus 1.5 inches extra height cut during first 6 weeks of chipping, when a streak ½ inch high was cut each week.

[b] Actual height plus 1.5 inches. During first 6 weeks of chipping the face was cut 6/4 inches too low since each streak was ½ instead of ¾ inches high.

[7] With the puller the cutting of the streak is done by the muscle power of the chipper, whereas with the hack the weight on the end of the handle makes it seem easier to cut the streak. This accounts for the fact that less wood is removed during pulling.

[8] MCKEE, E. R. OP CIT.

EXPLANATORY LEGEND FOR PLATE 2

Cross sections of chips cut Nov. 24, 1923 (end of season), from Groups 1 and 3. Longest sections show about ½ inch of wood.

Top row.—Chips from low faces, Group 1 trees. Note (1) wide 1923 annual ring next bark, at top, (2) with numerous resin passages; (3) most of the 1923 rings as wide as or wider than those of 1922.

Bottom row.—Chips from high faces, Group 3 trees. Note (1) narrow 1923 annual ring next bark, (2) with few resin passages; (3) 1923 annual ring often narrower than that of 1922.

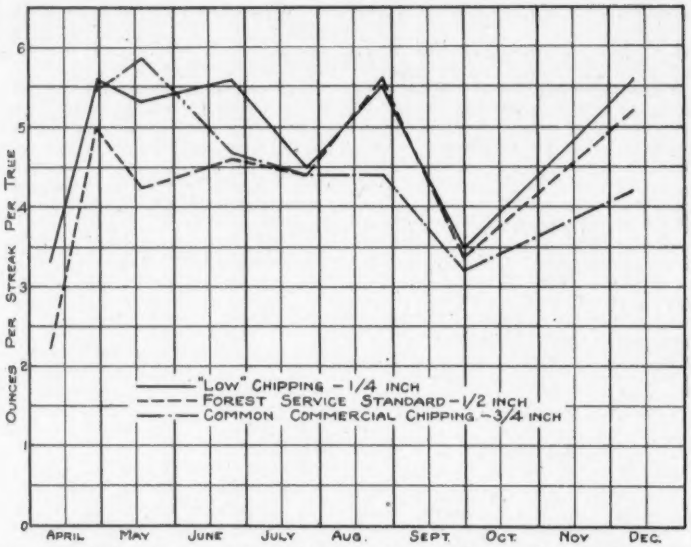


FIG. 1.—Yield of oleoresin per streak per tree in chipping test on longleaf pine, Camp Pinchot, Fla., 1923

TABLE II.—*Yields of oleoresin obtained in chipping test on longleaf pine, Camp Pinchot, Fla., 1923*

Date of dipping	Number of streaks cut since last dip	Yields					
		Group 1 (¼-inch chipping)		Group 2 (½-inch chipping)		Group 3 (¾-inch chipping)	
		Total for 20 trees	Per streak per tree	Total for 20 trees	Per streak per tree	Total for 20 trees	Per streak per tree
		Pounds	*Ounces*	*Pounds*	*Ounces*	*Pounds*	*Ounces*
Apr. 9 [a]	6	25.00	3.33	[b] 16.75	2.23	[c]	
Apr. 28	3	21.00	5.60	18.75	5.00	20.50	5.46
May 18	3	20.00	5.33	16.00	4.26	22.00	5.86
June 25	4	28.00	5.60	23.00	4.60	23.50	4.70
July 26	4	22.50	4.50	22.00	4.40	22.00	4.40
Aug. 27	4	27.50	5.50	28.00	5.60	22.00	4.40
Oct. 1	5	22.00	3.52	21.00	3.36	20.00	3.20
Dec. 10	4	28.00	5.60	26.00	5.20	21.00	4.20
Total dip for season	33	194.00	5.01 (0.313 pound)	171.50	4.59 (0.287 pound)	-------	4.48 (0.280 pound)
Comparable total dip for season	27	169.00	-------	154.75	-------	151.00	-------
Total scrape	-------	43.00	-------	42.00	-------	51.00	-------
Total comparable dip and scrape	-------	212.00	-------	196.75	-------	202.00	-------

[a] Dipping of April 9 not counted in comparable total because Group 3 was lacking.
[b] Chipped later in week than Group 1; full amount of gum not in cup at first dipping.
[c] Weight not taken.

The fact that the ¼-inch chipping gave a high total yield of gum and produced a particularly high yield during the latter part of the season is of great significance if found to be maintained in later years and confirmed by other tests. This is not the first time that such a result has

been clearly indicated. The fact that as much gum as usual, or even more, was obtained in this test from trees which had considerably less than half as large a scar as is frequently used is worthy of note. Not only is it a matter of scientific significance, the causes of which are to a considerable extent explained by studies of the microscopic structure of the wood, but it is a matter of practical importance as well. By lightening chipping an operator is at no additional expense; he is also, if this test is typical, obtaining at least as high a yield as with the old methods. Furthermore, he is keeping his trees more healthy and productive because reducing the size of the wound, and, lastly, he is reducing the source of possible lumber degrading due to pitch-soaking behind the face.

Additional data from this test and also results from "low" chipping experiments at other points will be available at the end of the 1924 season.

CALCULATION OF YIELDS ON A CROP BASIS

The yield from the last 27 streaks, those cut according to test requirements on the 20 selected trees in each group, converted to a yield per crop (10,000 cup) basis, is shown in Table III. In the test-yield figures the omission of the amount of gum obtained from the first 6 streaks to some extent compensates for the fact that the crop calculation is based on the yield of selected trees. Since the calculated figures may still be a little high, the possible excess has been further allowed for herein below by an arbitrary reduction in the estimated value of the products. The difference in response of the three groups appears to be a real one, as is shown in the microscopic data presented later.

For comparison, the average results of working trees on a commercial operation were obtained for the tract in which the test trees stand. Here 33,521 cups were included in a first-year working by methods the same as those employed in test Group 2. The yield [1] obtained was 618.4 barrels of gum and 212 barrels of gum and scrape mixed. The latter produced about 8 gallons of spirits of turpentine per barrel and the former about 12. Hence the total yield was approximately 9,116.8 gallons, or 182.33 barrels, of turpentine. The number of cups worked was equivalent to about 3.35 crops, so that the yield per crop (10,000 cups) averaged about 54.4 barrels of spirits. By calculation of the Group 2 yields, without any deduction, a production at the rate of about 60 barrels would be indicated. This, however, presupposes vigorous, healthy, comparatively young trees, which probably average higher in yield than many of the over-mature, old-growth trees which are of necessity included in the commercial working.

TABLE III.—*Conversion of test (20 cup) yield to a crop (10,000 cup) yield basis Chipping test on longleaf pine, Camp Pinchot, Fla., 1923*

		Group 1	Group 2	Group 3
Yield from gum:				
1. Actual net yield of gum from 20 trees (Apr. 9 to Dec. 10, 1923; first 6 weeks omitted)	pounds	169.00	154.75	151.00
2. Calculated net yield of gum for 10,000 cups	do	84,500.00	77,375.00	75,500.00
3. Calculated number of barrels of gum (net weight 410.5 pounds each)	barrels	205.85	188.49	183.92
4. Calculated quantity of turpentine (one barrel of gum yields about 12 gallons spirits)	gallons	2,470.20	2,261.88	2,207.04
5. Value at 98 cents per gallon	dollars	2,420.80	2,216.64	2,162.90
6. Number of barrels of turpentine (50 gallons each)	barrels	49.40	45.24	44.14
Yield from scrape:				
7. Actual net yield of scrape from 20 trees	pounds	43.00	42.00	51.00
8. Calculated net yield for 10,000 faces	do	21,500.00	21,000.00	25,500.00
9. Calculated number of barrels (net weight 310 pounds each)	barrels	69.35	67.74	82.26
10. Calculated quantity of turpentine (one barrel yields about 5 gallons spirits)	gallons	346.75	338.70	411.30
11. Value at 98 cents per gallon	dollars	339.82	331.93	403.07
12. Quantity of turpentine (50 gallons per barrel)	barrels	6.94	6.77	8.23
Calculated total yield, gum and scrape combined:				
13. Total quantity of turpentine per crop. (Selected trees, 27 streaks) (6+12)	barrels	56.34	52.01	52.37
14. Quantity of turpentine from commercial operation (all trees, 32 streaks)	barrels		54.42	
15. Total value of spirits (5+11)	dollars	2,760.62	2,548.57	2,565.97
16. Approximate total amount of rosin (No. barrels turpentine×3)	barrels	169.02	156.03	157.11
17. Value of rosin at $4.80 per barrel	dollars	811.30	748.94	754.13
18. Total value of turpentine and rosin per crop (15+17)	do	3,571.92	3,297.51	3,320.10

[1] From information furnished through courtesy of the administration of the Florida National Forest.

FINANCIAL ADVANTAGES FROM LOW FACES

Taking the average price of turpentine as 98 cents a gallon and of rosin as $4.80 a barrel,[10] it has been shown in Table III that there would be a difference in value of the products between the "low" or ¼-inch chipping and the "high" or ¾-inch, amounting to more than $250 per crop; or to be very conservative, since the calculated yield may still be higher than an actual one based on a large number of variously conditioned trees, say, in round numbers, about $200.

Before undertaking the test there was no clear indication of an actual gain in total yield to be had the *first* year. Results on a large number of less carefully matched trees had even indicated a lower first-year yield than from trees more heavily worked. The advantage of increased yield during *later years* was, however, expected, and the next three years will show whether or not the expectation was justified. The advantages of reduced size of scar and, consequently, of better sustained vitality in the tree, more prolonged working, and reduced degrading of the butt lumber were obviously assured from the start. These will remain significant whether the yields during the first year are to be slightly less, the same as, or greater than those obtained from heavier work.

MICROSCOPIC STUDY OF WOOD FORMATION IN THE TEST TREES

MATERIAL

The progress of wood formation above the face scar on the test trees was followed by means of a microscopic study of chips collected on June 6, July 26, October 19, and November 24, 1923, at the height of the face on those respective dates. An examination of increment borings made on the Group 1 and Group 2 trees when they were first selected had revealed no significant differences.

RESULTS OF MICROSCOPIC STUDY

It has been found as the result of extensive study and many painstaking comparisons between the structure of the new wood formed after turpentining (especially that midway of the streak just above the face) and the yields and behavior of the trees worked that chips such as those obtained serve as very reliable indicators.[11] They show whether or not a tree has its vitality so impaired that it is incapable of producing an adequate return. They show finer points also, which are made clear by a comparison with the responses of the round timber similarly situated during the same year. The degree of response in such matters as width of annual ring, percentage of summerwood, date of beginning of wood formation in the spring, time of summerwood formation, and amount and character of resiniferous tissue (duct) formation are closely coordinated with the method of turpentining. These indications can often be obtained, by microscopic examination, in time to save undue injury to the timber as a result of too heavy working.

MIDSEASON EXAMINATION.—Microscopic characteristics of the July 26 chips, representing the midseason condition of the trees, are recorded in Table IV, as are also the characteristics of the chips taken at the end of the season, November 24.

It is obvious that by July 26 a considerable portion of the wood of the 1923 ring had been formed. In more than half the trees in Group 1 as many wood cells were already present as were found in the entire ring formed during the preceding year (1922). In Group 3 this was true of only about one-third of the trees. On the average, the trees chipped ¼ inch each week (Group 1) had wider rings, more summerwood cells, and more resin passages than those of the two other groups. This seems to indicate an earlier and more vigorous response in the Group 1 trees. Indeed, at this time they had produced on the average nearly three times as many summerwood cells and about twice as many resin passages as the Group 3 trees. Presumably because of the low chipping and removal of little wood, the trees in Group 1 were able to make a better adjustment to the exploitation of their energies for gum production. This notable structural difference was approximately concurrent with the difference in yield of gum, which was particularly apparent for Groups 1 and 3 from about this time to the end of the season, as is shown by the graph, Figure 1. It further emphasizes the

[10] Based on figures for the 1923-24 season by SPEH, C. AVERAGE MONTHLY SAVANNAH MARKETS FOR SEASON 1923-24. Naval Stores Rev. 34 (2):17. 1924.

[11] GERRY, E. OLEORESIN PRODUCTION. U. S. Dept. Agr. Bul. 1064, 46 p., illus. 1922. —— RECENT OBSERVATIONS ON THE EFFECTS OF TURPENTINING ON THE STRUCTURE OF SECOND-GROWTH SLASH AND LONGLEAF PINES. Jour. Forestry 21: 236-241. illus 1923

relation between gum production, vitality, and number of resin passages present. In Group 1, besides the normal number of resin passages in the old rings, these relatively more abundant extra wound ducts were, as is apparent from the plates and Table IV, already formed and active by midseason. In Group 3 only about half as many were functioning at that time. Table IV clearly shows that the effects of different methods of working made a progressive series. The poorest formation of wood and resin tissue occurred in the Group 3 trees; an intermediate but good condition was found in Group 2, but the best response was made by the Group 1 trees with the lowest faces.

after regular chipping had stopped, a thirty-third streak was cut on the test trees in order to obtain a comparable set of fresh chips on which to study the effect of the season's work at a point midway of the streak at the top of the face. From Table IV it will be clear that a similar, though less marked, relation to that found at midseason still existed between the groups. The average width of the 1923 ring, the amount of summerwood, and the number of resin passages was greater at this time in the Group 1 trees than in those of Group 3. There was, it is true, a slight increase in the average total number of resin passages found for Group 3 in November above that present in July, but their number was

TABLE IV.—*Comparative production of wood and resiniferous tissue in height of chipping test on longleaf pine, Camp Pinchot, Fla., 1923*

	Average width of 1923 ring			Average number of resin passages in unit area,* per year		Number of observations in which width of 1923 ring was found equal to, less, or greater than width of 1922 ring		
	Springwood cells	Summerwood cells	Total cells	1923	Average for 3 years before turpentining	Equal or nearly so	Less	Greater
Chips taken July 26, 1923:						*Per cent*	*Per cent*	*Per cent*
Group 1 (¾ inch)	7.8	18.3	26.1	12.0	1.10	31.8	31.8	36.4
Group 2 (¼ inch)	11.0	12.9	23.9	9.0	1.08	5.0	40.0	55.0
Group 3 (¾ inch)	7.8	6.4	14.2	6.5	1.00	25.0	62.5	12.5
Chips taken Nov. 24, 1923:								
Group 1 (¾ inch)	12.6	19.2	31.8	11.4	1.12	2.7	32.4	64.9
Group 3 (¾ inch)	8.3	14.0	22.3	7.3	1.21	11.6	41.9	46.5

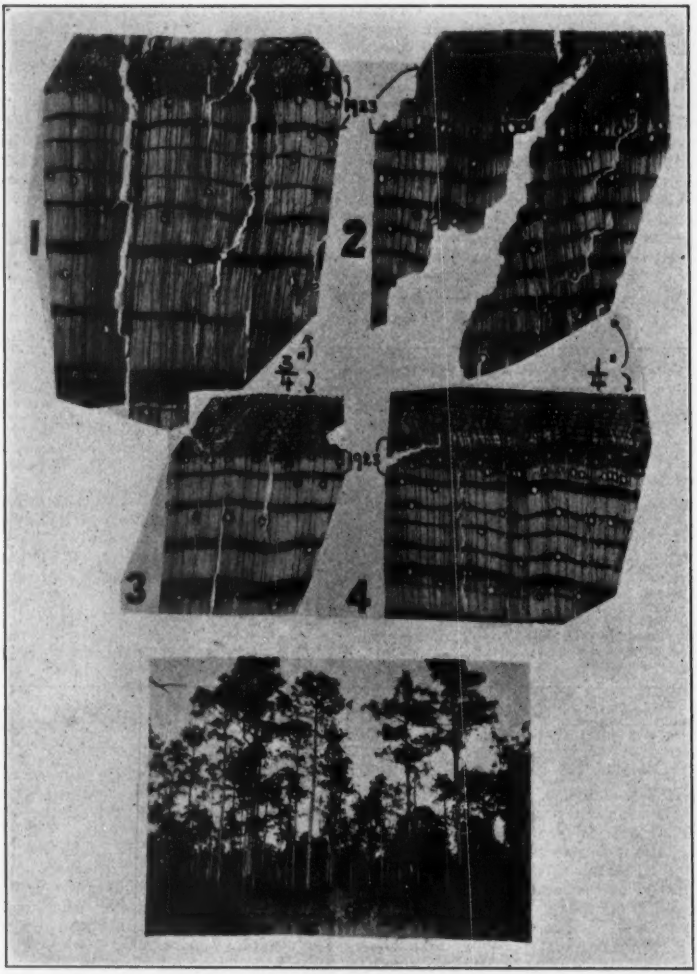
* "Unit area" is an arbitrary tangential extent; the diameter of microscopic field by the width of the annual ring observed. Used 32-mm. objective and 15× eyepiece, giving a magnification of about 60 diameters or 3,600 times the actual wood area observed.

The time and amount of summerwood formation appear to be significant factors in judging the effects of given methods of working. Over and over again resiniferous tissue has been found to be produced at the expense of summerwood formation. This is often very striking in the case of trees worked too severely. The production of early and abundant summerwood has been found, so far as the writer's observations extend, to be coincident with conservative working and conditions in which the trees have manifested ability to produce good sustained yields. Hence the fact that the trees in Group 1 had by midseason nearly three times as many summerwood cells as those in Group 3 appears worthy of note.

EXAMINATION AT END OF SEASON.—On November 24, 1923, two weeks

still exceeded by about 50 per cent by those of Group 1. On comparing the width of 1923 rings in each group with the width of those formed in 1922, it is seen (Table IV) that here also the Group 1 trees showed greater vigor of growth than those of Group 3. In Plate 2 are shown typical microscopic sections from chips from these groups. The tendency in Group 3 to produce narrower rings and fewer ducts is plainly evident, as is also the relative width of the 1922 and 1923 rings. At the left (Pl. 2) are shown sections from the most vigorous trees in each group; at the right some from the poorest ones. On the average, Group 1 produced growth rings almost 50 per cent wider than those of Group 3.

Another difference between the trees of Groups 1 and 3 is significant. Certain of the wound-induced resin



Top.—Cross sections of chips. Longest section represents about ½ inch of wood. Chipping high faces wastes much of the richest and most productive resiniferous tissue before it can yield fully. It cuts away the early-formed, comparatively short resin passages. These are seen in chips 2 and 4 in springwood of the 1923 ring next bark (top), but are lacking in chips 1 and 3.

Bottom.—General view of test area.

passages, particularly those formed in early spring, are comparatively short. By taking off high chips these are cut away before they have had an opportunity to yield the gum which they are capable of producing. With such chipping, potentially valuable wood full of highly organized and productive tissue is cut off and thrown useless on the ground. In Plate 3 it is to be seen that no resin passages are present in the early springwood of the 1923 ring of the specimens from the trees of Group 3. Here the early springwood had probably contained resin passages in June or July, but these, or at least some of them, were short and were probably entirely removed by the time the face reached its final height (21 inches). The cutting away of such resin passages is one of the marked wastes caused by high chipping. To be sure, there still remain many passages which are longer and will continue to produce gum, but a large percentage of available producing power is thus needlessly wasted, despite the fact that conserving it as long as possible presents distinct advantages from every point of view.

Observations have shown that in a given growth ring a considerable reduction in the number of resin passages occurs from 1½ to 3 feet above the early streaks of that year's work. In one instance only half as many resin passages were present in the face at 2 feet above the first streak as were present at 1 foot up. The effect on wood formation of the wound of turpentining may, however, be much further extended vertically. Often the early virgin streaks affect the wood formed for 20 or more feet above, in respect to number of resin passages, width of ring, or amount of summerwood. The greatest number of resin passages, however, have been found in a comparatively limited region of a few feet above the early streaks of a given year.

Low chipping permits the operator to take advantage of this area for the longest possible time. The presence of the many resin passages in the very early springwood of the specimen Group 1 trees represented in Plate 3 is an instance of available productive capacity which may be utilized. The faces on these trees were only 10 inches high. In such trees there is obviously a reserve of highly productive tissue present with which to start the second year of operation. These resin passages will augment the yield until the freshly induced passages of the succeeding year develop and begin yielding at their maximum.

Methods for building up one or more rings of such rich and productive wound tissue before starting regular turpentining are now being tested and present some very interesting possibilities.

DISCUSSION OF RESULTS: NEW WORK

It is common knowledge among practical operators that all that is needed to freshen a streak on a turpentined pine sufficiently to secure a flow of gum is to remove the layer of wood forming the surface of the streak. The dimensions of the layer, however, vary widely in the practical application made by different woodsmen.

After the cut surface of the streak has stood for a few days exposed to the air the wood cells tend to dry and to soak up gum, which they will not do when they are freshly cut and moist. It is then said that the streak has "lightwood" in it. Also, the gum which has flowed out from the resin passages dries and hardens to some extent on the streak surface, owing to evaporation of the volatile spirits of turpentine. At and near the surface of the streak certain of the cells have been injured or killed by the chipping. It is obvious that these destroyed cells and the dried abnormal tissue must be removed.

Undue drying frequently results from chipping too deeply. This practice tends to cause excessive soaking in of gum and the formation of a considerable amount of "lightwood." If such a streak is chipped only ¼ inch high not all the "lightwood" may be removed. This result, however, does not necessarily prove that a higher chip should be cut. Rather it should suggest the possibility that perhaps the too deep chipping has caused interference with the circulation of the watery sap of the tree. It is obvious that enough sapwood should be left behind the face to insure the moisture necessary to keep the living cells healthy and productive. Years of work on the Florida National Forest have shown that with ½-inch-deep chipping healthy conditions are maintained even in trees in which the sapwood is not very wide. Studies of the effect of other depths of chipping are now under way at the Starke station and elsewhere. It is sufficient to say, at this time, that much of the criticism of low chipping, as, for instance, the statement that it "will not keep ahead of the lightwood," or will not remove all the gum-soaked surface of the streak, and that it will radically reduce production, has resulted from observation of trees which were already

chipped so *deeply* that they were drying and soaking unduly. Such trees would obviously not present fair material from which to determine the effect of height of chipping.

Good production has been obtained with the ½-inch-deep and ½-inch-high streak on the by no means superior timber of the Florida National Forest.[12] The question then naturally arises whether or not it is possible to reduce still further the height of the layer of wood removed weekly. Observations indicate that an eighth of an inch, a mere shaving of the surface, will not produce the effects desired; it can not be depended upon to remove the gum-soaked and abnormal surface tissue. In all cases, however, where good average ¼-inch-high chipping of a safe depth has been used, reasonably satisfactory results have been obtained. In view, therefore, of the many indications of good results of conservative chipping in general, and in view of the particular results of this test, it seems safe to work toward chipping lower faces.

The lessened damage to the timber of such turpentining practice is a matter that can not fail to appeal to the owner of the forest and to the sawmill interests. Even the chipper, experience proves, once he has found that it is possible to take off less wood, readily falls into line. To be sure, he is somewhat averse to the longer period during which he must stoop to perform chipping low on the butt of the tree, but he is, on the other hand, spared much longer the hard work of pulling. The expenses of cup raising could be somewhat reduced by cutting lower faces. This is an item worth considering, as is the saving in spirits due to the fact that the gum does not have to go so far to reach the cup. Furthermore, turpentine camps might not need to be moved so frequently. If results continue to demonstrate the fundamental scientific soundness of the principle as well as its numerous practical advantages, the argument in favor of lower faces for commercial production would seem conclusive. At first, perhaps, No. 1 or No. 0 hacks should be used to remove the commercially successful and thoroughly tested ½-inch-high chips, and the streak then gradually reduced to as nearly ¼-inch-high chipping as may be practicable.

For 1924 it is planned to test low chipping at Cogdell, Ga.; Lockhart, Ala.; Holopaw, Opal, Starke, and Camp Pinchot, Fla.; and at several points in Mississippi and Louisiana

SUMMARY OF RESULTS

Evidence obtained from preliminary tests, notably the carefully conducted though comparatively small one here described, and from practical experience indicates that many advantages (reduced scar, less lumber degrade, longer possible operation, higher sustained yield, and conservation of tree energy) may be gained by cutting comparatively low faces (10 inches to 16 inches yearly at most). Such cutting has been satisfactorily accomplished by using a No. "0" hack.

In the test described, three carefully matched groups of 20 trees each were chipped to the same depth (½ inch) and to a height of approximately ¼ inch for Group 1, ½ inch for Group 2, and ¾ inch for Group 3. The Group 1 trees (actual average height of chip 0.28 inch) produced a higher total yield of gum during the first year of the test (1923) than was obtained from the trees of Groups 2 and 3 with higher faces.

The trees with low faces showed earlier and more abundant wood formation (especially summerwood) and a greater amount of gum-yielding tissue (resin passages) than the trees with the higher faces. By midseason (July) they showed nearly twice as many wood cells (including about three times as much summerwood) and about twice as many resin passages formed and ready to function as did the Group 3 trees which were chipped ¾ inch high each week. This would indicate better sustained vitality in the low-chipped trees, and hence would explain the higher producing power which was manifested in their yields.

Preventable waste is caused by high chipping, since it removes more than is necessary of the rich gum-bearing tissue before it has had time to produce the yield of which it is capable. Microscopic study of the number and location in the ring of the resin passages at different heights in the face demonstrated that the early-formed, comparatively short wound ducts are quickly cut away by high chipping. Low chipping permits the longest maximum production in any year, since the face is cut in the region richest in resin passages. Low chipping also makes it possible to hold over a reserve of this tissue to augment

[12] McKee, E. R. Naval stores production on the Florida National Forest. Naval Stores Rev. 33 (6): 16-17; (7) 6, 23; (8) 6, 19; (9) 10, 23; (10) 16-17. 1923.

production during a part at least of the following year.

Since extra numbers of resin passages develop as a result of wounding, tests are now under way to determine whether the productivity of low faces can be increased further through stimulating advance resin tissue formation by means of slight wounds (such as inserting the gutter) a year or more in advance of the first regular work.

In the present tests it is significant that although ¼-inch chipping gave a comparatively low yield early in the season it produced during midsummer and fall not only as much as ¾-inch chipping but even more—at the time when severely worked trees frequently show a tendency to dry-face and fail.

The low faces, as compared with the high, showed a considerably increased value of products because of their higher yield. Converting the yield of the 20 test trees in each group to a yield per crop basis, a rough but conservative calculation indicates a difference of $200 in favor of the low faces.

Cutting of low faces (with a streak less than ½ inch high) is under continued test in 1924. On several other small experimental tracts carefully matched slash and longleaf pines of various ages and in varying environments are being worked. It is clearly recognized that the present results obtained from one year's work on a comparatively small number of test trees can only be regarded as indicative. The ¼-inch chipping is now being tried on a commercial scale by practical operators who, for their own information, are comparing the yields from crops or portions of crops (drifts) as the case may be. It is expected that some significant results will be available at the end of the 1924 season.

THE EFFECT OF BACTERIAL NUMBERS ON THE NODULATION OF VIRGINIA SOY BEANS[1]

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Since the discovery that legume nodules are caused by bacteria, many questions have arisen as to the factors which effect the maximum nodulation obtainable. One little-considered factor which affects nodulation is the number of *Bacillus radicicola* organisms present in the substrata. It is but logical to suppose that the greater the number of infecting organisms present the greater will be the number of nodules produced. The proper number of organisms to be used for inoculation is a question since most limed soils favor the reproduction of this organism and, consequently, a scant inoculation will serve to assure the presence of large numbers of infecting organisms. It is maintained by many investigators that after legumes have become nodulated to a certain extent they are immune to additional infection. If this is so, increasing numbers of bacteria should increase nodulation only up to a certain point. The accompanying data show that nodulation will be limited if the number of infecting organisms is limited and that there seems to be an immunity set up in the plant after it has become inoculated to a certain degree.

The nodulation data were obtained from plants grown in washed sand. The sand was fertilized by saturating it with a mixture composed of 0.08 per cent of magnesium sulphate, 0.15 mono basic potassium phosphate, 0.50 per cent calcium carbonate and 0.05 per cent ferrous sulphate dissolved in distilled water. Subsequently, the substrata were maintained 75 per cent saturated by daily waterings with distilled water. The crop was harvested after four weeks' growth. In making the inoculations an emulsion from a one-week-old culture of the organism was standardized by counting with a haemcytometer and diluted to the required degree. The amount of water that a given quantity of seed would absorb was determined and the dilutions were made so that this volume of emulsion would contain the desired number of organisms. Laboratory tests indicated that the fertilizing mixture used would not permit the reproduction of the organism in the absence of an available carbohydrate but that it contained nothing toxic to the bacteria. Therefore it is seen that the substrata used would keep the numbers of infecting organisms practically constant. The plants were grown in tumblers containing one pound of sand. Twenty seeds were planted in each tumbler and the seedlings were thinned out to the ten best. The experiment was conducted in triplicate.

Table I indicates that maximum nodulation may be obtained when the number of infecting organisms applied is between ten and one hundred per seed. Table II shows that maximum nodulation may be obtained when the number of infecting organisms applied is between twenty-five and fifty.

TABLE I.—*Effect upon nodulation of increasing the number of bacteria*

Tumbler No.	Number of organisms applied per seed	Plants inoculated	Number of nodules per 10 plants
		Per cent	
1A	0	0	0
1B	0	0	0
2C	0	0	0
2A	1	0	0
2B	1	0	0
3C	1	0	0
1A	10	40	12
3B	10	80	24
3C	10	70	25
4A	100	100	63
4B	100	100	73
4C	100	100	50
5A	1,000	100	71
5B	1,000	100	65
5C	1,000	100	80
6A	10,000	100	72
6B	10,000	100	78
6C	10,000	100	84

[1] Received for publication June 11, 1924. Paper No. 173 of the Journal Series, New Jersey Agricultural Experiment Stations, Department of Soil Chemistry and Bacteriology. Part of a thesis submitted to the faculty of Rutgers College in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2] The author wishes to express his appreciation to Dr. J. G. Lipman for helpful suggestions in planning this work.

TABLE II.—*Effect upon nodulation of increasing the number of bacteria*

Tumbler No.	Number of organisms applied per seed	Plants inoculated	Number of nodules per 10 plants
		Per cent	
1A	0	0	0
1B	0	0	0
1C	0	0	0
2A	1	0	0
2B	1	0	0
2C	1	0	0
3A	10	1	3
3B	10	1	5
3C	10	1	4
4A	25	100	48
4B	25	100	62
4C	25	100	51
5A	50	100	60
5B	50	100	68
5C	50	100	71
6A	100	100	59
6B	100	100	66
6C	100	100	73
7A	500	100	65
7B	500	100	78
7C	500	100	63

Both tables show that a high number of infecting organisms will not give a better inoculation than a moderate number. Theoretically, it seems that infection and nodulation are partly a hit-or-miss affair. When a limited number of nodular organisms are present the chances of contact between host and bacteria are naturally not so great as when a large number of organisms are present. Therefore the greater the number of infecting organisms the greater should be the number of nodules produced. This ratio between bacterial numbers and nodulation holds only when the number of organisms is very limited and approaches infinity as the number of bacteria is increased. It is therefore apparent that there must be a maximum infection obtainable and that after this maximum is reached the plants become immune to additional infection.

The conclusions to be drawn are:

1. When the number of nodular organisms is limited there is a distinct relation between the number of organisms present and the number of nodules formed.

2. There is a rather definite minimum number of nodular organisms required to produce maximum infection.

3. After a certain degree of infection is reached the host is immune to additional infection.

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